SOLAR HEAT

SOLAR HEAT

Its Practical Applications

BY
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and other works

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PREFACE.

SUNLIGHT is a common word, its meaning early and universally appreciated.

Why should not "sunheat" be as fully understood, as highly estimated as its twin? For every ray of illumination which comes to us from the sun is entwined with a ray of caloric, equally strong, equally beneficial. And as the *light* of our orb of day has obtained admiration and won praise for vitalizing and enriching processes in nature and art, why should not fervid poetry and cool ledgers give due credit to the *heat* of the sun for the life, health, power, and wealth which it is capable of conferring to a degree but slightly recognized? And why shall we not take possession of this opulence promptly, eagerly, masterfully?

This book seeks to arouse every one of its readers, especially the young and progressive, to take part in and help forward a world-wide movement in the appropriation of the vast treasures which sunheat offers.

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INTRODUCTION.

MAN, relying only upon his own strength, exercise of human muscular force, can acc plish very much. He may fell trees, rive tl trunks into timbers, boards, shingles, pins, tools, and put these together, making for h self a commodious and convenient dwelli With one of the bits of stone or metal that ture has strewn upon the surface of the grou he may chip off other chips, and bring to an e tools for his use in cutting wood, stone, metals. Learning by experiment what can done with the wedge, the lever, and the rol he can move great masses and build structu of immense size. Braiding the fibres of pla into ropes, he can draw and lift weighty a cles; twisting them into yarns and cords, can then weave them into cloths for a great

riety of uses, to protect and ornament the body and perfect the convenience and comfort of his dwelling. On instruments made entirely by hand wonderful melodies and harmonies have been produced; on hand-smoothed wood and hand-woven cloth poems and histories have been written, mathematical problems calculated, and artistic conceptions wrought. Making use of the vital energy which he finds operating in plants and animals, he tills the soil and raises stock, till farm and garden and flock and herd reward his toil.

Having discovered fire (first becoming acquainted with it, perhaps, as a product of lightning), experiment shows him the value of heat to improve the quality of fruit and flesh and to bring metals into plastic condition. Then, still making use of human power alone, he has gone on enlarging the sphere of his activities, the wealth of his achievements.

But at a period very remote, man learned to domesticate animals, and add their force to his own. He bade them draw his plow, tread out his grain, move his heavy loads, and bear his

burdens. Next, he turned to the wind, which often hindered his movements, and tamed it to be his servant. Stretching with his own hands the fans and sails of his mill, he calmly awaited the approach of the gale, and laughed as the attacking party became his servant. He spread the cloth his hands had woven on the spars his fingers had shaped, and the conquered wind became his galley-slave. The torrent rushing down the hillside was caught by his nimble fingers, and made to do his bidding, turning his water-wheel. By and by a compound force was invented, — Steam, — child of the father Fire and the mother Water, a very Samson. Now the progress of man's achievements became, shall we say, a thousandfold greater than before? Surely man, with the auxiliary steam, has been writing history at a prodigious rate compared with his former movements.

One more tremendous force has been brought into man's possession and use, — rather a triad of forces, Magnetism, Galvanism, and Electricity. The first was domesticated by the almond-eyed citizens of the Central Flowery Kingdom

ıany centuries ago in the mariner's compass; ıe other two coquetted with philosophers for a ɔng period; but the trio to-day are saddled and arnessed for the every-day service of the rich nd poor alike in a multitude of ways.

What more do we need? Have we not forces nd machinery sufficient for all present and propective uses? We are still improving all the uxiliaries which we have adapted to our use; till learning the laws of heat; still improving ıe breeds of our domestic animals; still invesgating agricultural processes; making innuıerable improvements in steam and electrical nginery, and so on.

MAN IS CRIPPLED FOR LACK OF AUXILIARIES.

But meantime, *the opportunities and demands f human activity have increased far more raplly than the exercise of human power, or the pplication of known principles, or the appropriion of external forces; and man is crippled ɔ-day for lack of auxiliaries.* It costs too much ɔ raise many of the articles which are needful

for the support of life; it costs too much to make many of the things which have come to be recognized as essential to a complete existence and happiness; and an immense sphere for discovery and appropriation still awaits us after all the years of man's residence on this planet. We must have more of the sort of help that the wind gives; more of such aid as steam furnishes; more of the service now rendered us by flowing streams and burning liquids and gases. Some other Titan must be found to bear our loads, till our fields, warm our dwellings, develop our mines, and extend the sway of our race over the irrational and inanimate.

One large motive to this search for, and appropriation of, a new auxiliary is the frightful destruction of material which is carried on by our fuel systems. Forests are being swept away from hills and valleys; coal is being drawn up from miles and miles of mines. The year 1902 has added an awful chapter to the history of our need of a new source of heat and power, by the wide suffering and impoverishment of the people of the eastern United States, in consequence of the

Pennsylvania coal strikes. Can we not discover or use, if already discovered, something which will be obtainable without the consent of either "operators" or "organized laborers?" *Can we not employ something which will still remain for to-morrow after we have used it to-day?* As the flowing stream gives its aid, so may not other natural movements be harnessed into our service? And is there not something more stable than the river current, which depends for its fulness on rainfall and other conditions?

PERSONAL EXPERIENCES OF THE WRITER.

This quest has long interested the writer. Becoming a resident of California in 1865, he saw much of the country from North to South. In the year 1875, living in Oakland, he began a series of experiments in the investigation of

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He used lenses first, "burning glasses," reading-glasses, photographic lenses, etc. It was

interesting to watch the varying operation of lenses of different size. A pocket magnifying-glass, one inch and an eighth in diameter, would concentrate heat enough to set paper on fire in a tiny spot in a second or more. The larger the lens, the broader the spot or section, which would flame up and burn out the paper in the same time. A glass three inches wide would set wood afire; one six inches across would bore a hole through a shingle; one of eight inches diameter would burn very hard wood, and inflame a disc the size of a dollar on the paper. Then the investigator turned his attention to reflectors. He saw the light streaming out in front of a locomotive from the silvered headlight reflector; there the rays of a lamp were sent against the inner walls of the reflector and then turned away in parallel lines along the track. The old maxim came to his mind: "What will fetch will carry;" the rays of the sun, falling in parallel lines on the inner surface of the reflector, will be reflected to the focus where now the lamp is placed. And the heat of the sun can be concentrated as well as its light, since both are under the same laws

of undulation. Impressed with this idea, he borrowed of the master mechanic at the railroad shop a spare headlight reflector; took it to his residence; set it up in a simply constructed framework, and inserted at the focus, where the lamp had been, a tube of galvanized iron, blackened. Turning the frame toward the sun, so that the rays fell directly into it, he waited five minutes only, when the quart of water he had poured into the tube began to boil; later he cooked eggs in the water, and did other culinary performances not needful to detail. Placing pieces of wood at the focus, he found them quickly burned; antimony glance, a metal of low melting point, soon flowed at the focus, and some other metallic compounds yielded also.

If the parson had been a mechanical man, able to construct apparatus, or, if he had possessed spare cash for the employment of skilled helpers, there might have been some valuable progress made. Unable to pursue the investigations farther at that time, he contented himself with filing, through the patent agency of *The Scientific Press,* of San Francisco, a caveat for an inven-

tion of *a transmitter* of heat obtained from concentrated solar rays.

EXTRACTS FROM THE CAVEAT.

The Theory.

1st. That the rays of the sun fall in parallel lines, and may be focalized in a point by refraction on one side of a given plane, or, by reflection, meeting like the radii of a sphere at its centre, from every side except that exposed to direct rays.

2d. That the parabolic mirror is the best form of reflector, and that its surface may either be polished or glistening white, *e. g.* "hard finish;" the latter by far the least expensive.

3d. That machinery of the simplest sort will give to such a mirror a motion which will keep its face toward the sun, even if its size be exceedingly large.

4th. That the degree and amount of heat at the focus will be proportionate to the area of the opening of the lens or mirror; and that, thus, the only limit to the temperature which may be

reached is the size to which such lenses and mirrors may be constructed and revolved.

5th. That the temperature of the air through which rays pass immediately before focalization affects the focal temperature. From which it would follow that the hot, rainless districts of the Sierra Nevada *et als.* will afford a very high degree of heat, and that there would be some accumulation of heat in some proportion to the time of exposure of surface.

6th. That any substance may (practically) be heated at or near the focus which does not injure the surface of the reflector by steam, smoke, or decrepitation; and *any* substance may be *retorted* there.

7th. That the best form of retort is spherical or spheroid, with conical apertures pointing toward the centre; which would multiply the heating surface like boiler tubes. The delivery pipe from this retort to be passed (1) directly back through the shaded portion of the reflector, or (2) forward and down through a slit in the reflector on to a rotating table. For melting

ores, the first may admit the ore, the latter conduct out the liquid.

The claim was then given:

"A is a parabolic mirror, which is mounted upon a suitable frame, and with the proper solar mechanism for rotating it, with its face constantly to the sun."

The device for which the inventor particularly sought protection was described as "An opaque, globular retort, B, provided with numerous conical spaces which extend radially toward the centre, and serve to carry the heat throughout the interior space, from which it is conveyed by a tube, C, through the rear of the mirror to the distributor, D. The discharger may consist of numerous conical spaces, E, which project radially in every direction from the central globe, D, into the medium to be heated, and by this or some equivalent device I am enabled to utilize the heat of the sun for many purposes. The concentrating and diffusing devices are especially useful for many other purposes, and I desire to especially protect myself in the use of these parts," etc.

This, the writer believes, was the first application at the United States Patent Office for anything relating to solar heat.

It may be of small value; but the point was made as a beginning of inventions for which he hoped to get time later on. He made the matter no secret; talked with many friends and acquaintances of it. One friend was a reader of the *Scientific American,* and called the writer's attention to the article which appeared in that journal, touching the French discoveries and constructions in the matter, of which he had been utterly ignorant before. From that time he regarded himself as a pledged *student* of the subject, and read what he could find, and find time for.

The date of the application for the caveat above mentioned was April 10, 1875; the date of the *Scientific American's* article on the French invention was September 13, 1875. The writer allowed the matter to pass until after he had removed to the Atlantic coast again. March 22, 1883, residing at Farmington, Maine, he contributed to the *Lewiston Evening Journal*

(known as "Congressman Dingley's paper") an article, in which he gave some history of the development of the applications of solar heat; and this paper was reprinted from the *Journal*, and issued in pamphlet form under the title, "Solar Enginery." Copies of the pamphlet were placed in a number of the leading libraries of the world, and sent to some persons notable in science or prominent in government; responses came back from a good number of them; and the writer had much pleasure in finding that he had opened a new field of thought and investigation to quite a large number of persons. Certain errors in his historical statements were kindly pointed out, and proffers of assistance and coöperation made by some. But a very busy life hindered him from contributing anything of importance to the study. He spent some money and time in experiments in certain classes of apparatus, but without marked success. Some of his correspondents were aided by him and did better.

He has seen some progress made in public interest in the subject; carping criticism and

scorn have passed pretty much away; every time he has given "talks" on the matter, he has been rewarded by active questioning and by positive respect shown the topic and his statements. Meantime the enterprise of California and Massachusetts has, as public fame declares, brought things to a practical success in certain cases; the demonstration is complete along some lines; and there ought to be from this very point definite progress along the whole front. There is a hesitation, however, a failure to advance rapidly. The writer believes that

SOME CALL TO THE PEOPLE

is needed; some information on the subject furnished in a manner to arouse interest and make a demand for the ovens, furnaces, engines, which it is possible now for manufacturers to produce. It is also necessary that some stir come to inventors, to ingenious men, handy men, to anybody who can find out new ways of "catching the sunbeams" and extracting gold from them.

THE PURPOSE OF THIS BOOK.

Therefore he comes before the public in the present treatise, in which he endeavors to trace the history of attempts and successes in the utilization of solar heat; examine a portion of the laws and limitations of the subject; discuss ways and means; and attempt to arouse his readers to give to the matter their energy and invention, their brain and capital; that we may very soon see solar enginery take its place by the side of steam enginery and electrical enginery and gas enginery in the public estimation, in technical schools, in mechanical journals, and in myriads of practical, labor-saving constructions.

SOLAR HEAT

Its Practical Applications

CHAPTER I.

SOME HISTORY OF SPECIAL UTILIZATIONS OF SOLAR HEAT.

THE earliest instance on record of the practical application of solar heat to aid man in his undertakings is *the alleged attack* of a Syracusan scholar upon the Roman fleet in the year 214 B. C. *with burning mirrors.*

Syracuse was the largest city of ancient Sicily. Long independent, many years an ally of Rome while its intelligent king, Hiero, lived, it had been estranged from the Italian government by his grandson and successor, Hieronymus, and

had allied its fortunes to those of Carthage. Marcellus, the Roman ruler, came down upon the city with his imposing force of ships, and the struggle was severe. Archimedes, the most renowned mechanician of the age, discoverer of the ratio between the circumference and diameter, and of the law of specific gravity, who had been a pupil of Euclid in Alexandria, set himself to work to aid his native land. He bethought himself of the mighty power of the sun. So he caused, as is supposed, a number of brazen plates to be constructed; had their surfaces polished to the highest degree possible, and then arranged them along the shore in some way not clearly described, so that the reflected rays were concentrated upon the hulls and rigging of the Roman ships which lay in the harbor or sailed near the shore, setting some of them on fire, and striking terror into the hearts of the sailors to such an extent that the fleet was temporarily scattered, and the city rid of their presence for a brief period. The siege was renewed after a little, to be sure; the inventor was struck down by the sword of a Roman soldier; and Syracuse

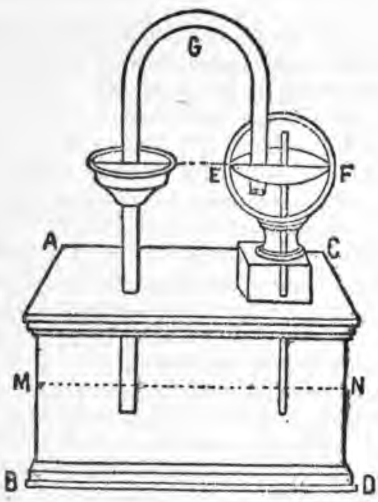
became a Roman province. But the philosopher's use of the sun's heat had taken its place upon the world's arena, and was entered in the world's records.[1] Later historians made something of it;

[1] Anthémius de Tralles, a celebrated architect, whose chief monument is the superb basilica of Ste. Sophia in Constantinople, dying in the year 584 A. D., left among his writings four treatises upon burning mirrors, fragments of which are still extant. The second of these is on the problem, "How to construct a machine capable of setting an object on fire at a distance by means of solar rays."

Roger Bacon, an English monk, advocated the use of burning mirrors about the year 1280 A. D., and actually constructed and offered for sale at £10 apiece some excellent ones of steel. But his genius and progressiveness made him enemies, and brought him obloquy and long imprisonment. He died in the year 1294.

Mirrors were manufactured in Dresden, about 1755, by a mechanic named Hoesen, of parabolic form, nine feet and a half in diameter, constructed with wooden frames, having thin plates of brass for a reflecting surface within. With these he and his patrons experimented in setting fire to objects at various distances; but we have no record of their applying them to the needs of the home or the factory.

Salamon de Caus (1576—1626), a French engineer, invented and described in 1615 the first machine for raising water by means of the heat of the sun. Another French engineer, Bernard Foret de Belidor (1697—1761), gives an excellent account of this "continual fountain," as its designer termed it.



THE CONTINUAL FOUNTAIN OF SALAMON DE CAUS (1615).

but it would seem that the event was looked upon as a freak, a piece of magic, an eccentricity; no successor of the great Archimedes arose for centuries to carry out his incomplete designs, or produce in full what he had performed in embryo. In fact, the time came when many students of history scoffed at the record of the burning of the fleet, and called the story a fable, a canard.

But there arose a man, after nineteen centuries had gone, who determined to test the practicability of the alleged performance of Archimedes. The French naturalist and philosopher, Buffon, about the year 1747, made a series of experi-

After filling the dome, A B N C, to the line B C, the heat of the sun on the dome so expands the air in its upper portion that the pressure drives part of the water (which cannot go down on account of the valve at K) up through the valve F into the reservoir H. When (at night, for example) the globe is cooled and the air in it expanded, water will rise from below through the valve K and the tube K N, until the air in the globe is condensed to the same degree as the outer air which presses upon the surface, M I, of the water below. This cycle will be repeated every day and night when the one is sufficiently warm and the other sufficiently cool. Of course artificial cooling might be applied and frequent cycles secured. [Mouchot.]

ments which demonstrated completely the entire practicability of the performance attributed to the Syracusan in the third century before Christ.

M. Buffon caused a large framework to be built, on which he hung pieces of silvered glass, whose reflections were all turned on one point. Then he varied the number of pieces and the distances of objects, which he subjected to the focalized heat of the sun, and tabulated the results.

With 17 mirrors, at 20 feet, he heated thin pieces of iron to redness.

With 45 mirrors, at 20 feet, he melted a pewter flask of six pounds' weight.

With 128 mirrors, at 150 feet, he burned a tarred plank.

With 154 mirrors, at 150 feet, he made a tarred plank smoke in two minutes when the sky was obscured.

With 154 mirrors, at 250 feet, he burned chips of wood covered with charcoal and sulphur.

All this was done in France, where the temperature of solar rays could not have been as high as at Syracuse, making a perfect proof of the *historical probability* of the story told by the

old historians concerning the Syracuse ship-burning.

M. Buffon afterward had a burning mirror, of parabolic form, constructed, having a diameter of forty-six inches, and performed many experiments with wonderful results. He does not appear to have looked on the sun as a tamable force for man's daily use, an ally for human enterprise; and all his experiments were classed by the annalists of the period as play, or, at the highest, scientific curiosities.

De Saussure, a Swiss philosopher (1740-99), in letters to Buffon and to *La Journal de Paris* described a set of concentric glass chambers which he had constructed, and in the interior of which he had cooked soup. About the same time a French physicist, Ducarla, constructed a somewhat similar apparatus and performed much the same work with it. [Mouchot.]

In 1764, B. F. Belidor published, at Amsterdam, the results of certain investigations of his own; but the world received no impulse toward the appropriation of the energy of sunbeams for real service. Even Sir John Herschel, when at

the Cape of Good Hope, in 1838, he was impressed with the tremendous power of the sun, failed to arouse anything of a practical spirit in the British mind.

For further accounts of ancient studies and constructions, see extracts from Mouchot in the Appendix.

Antoine Poncon, in 1854, obtained a patent in London, the first of which I have found any record, for an invention to utilize solar heat.

"My invention," says the patentee, "consists in using the sun's rays to create a vacuum in a suitable vessel, elevated at the height of a column of water, which, in the above vacuum, is kept in equilibrium by the pressure of the atmosphere. Such vacuum being formed, I fill it with water acted upon by the external pressure of the atmosphere, and thus obtain a head of water which may be applied as a motive power." Nothing more can be learned of this invention. Whether M. Poncon actually constructed a machine and produced a vacuum after this sort, and did obtain a head of water which he really used as a

motive power, or whether he obtained *a patent for an idea* (as many an inventor has vainly tried to do under our American laws), no man informs us.

In 1865, William Graham McIvor, superintendent of the Government Botanical Garden and Cinchona Plantation in the Presidency of Madras, India, obtained a patent in England, also, and Colborne and St. George a little later; but there comes to the reader a strong suspicion that the Patent Office admitted essayists, rather than inventors, to their lists; and that these men were not actual makers of machines which did what they claimed. Especially is this true of McIvor, who tells us, "on the average we have 280 bright days in a year, when the unconcentrated heat of the sun is all the way from 120 to 160 Fahrenheit." But he does not explain anything he had done to utilize it.

While these studies and declarations were going on in Great Britain, and nothing more tangible is recorded, there was a definite advance made in France, the home of Buffon, above mentioned.

AUGUST MOUCHOT,

a professor in the Lycée d'Alençon, at Tours, in the southern part of France, pursuing studies in mathematics, the department in which he was an instructor, achieved some very practical results. He made a reflector of a general parabolic form, like the headlight reflector of the locomotive (see Introduction), and placed at the focus a boiler filled with water, covering it with a bell-glass; he connected the boiler with a small steam-engine, which was run by the heat of the sun alone. This "insolator" was a success to some extent; he seems to have actually had it in operation as early as the year 1860. At about the same time he invented ovens, "*les marmites solaires,*" in which he cooked food to a certain amount. He exhibited a solar pumping-engine in Paris in 1866. [*Revue des Deux Mondes,* 1876.]

The government became interested in his work, and aided him; employed him, in fact, to construct a number of pumping-engines for use in their province of Algeria, on the desert.

These were not made, perhaps, before the exhibition, in 1875, of his perfected reflector and engine, but some of them were in operation in 1878. He exhibited at Tours, and afterward at the Paris Exposition in 1878, a reflector 112.3 inches wide, 39.3 inches at base, with an engine at the focus, which pumped water very rapidly and worked successfully. He obtained patents for various forms and parts of his inventions in France, and also in England.

All must unite in honoring him as the greatest of the pioneers in solar enginery. The world owes him a large debt.

POSTSCRIPT.

After the present work had gone to press the writer, being in London, saw for the first time M. Mouchot's book, "*La Chaleur Solaire, Ses Applications Industrielles,*" in the library of the British Museum. He immediately ordered a copy and read it, with keen interest and admiration. From its pages he made, on his return to America, a few extracts which he incorporated in the final

oof-reading of this volume, giving credit for e same in every case; he also added in an pendix a translation of the title and contents of . Mouchot's work, in order that his readers ght get something of the benefit which the ofessor's pages afford.

M. Mouchot began to give his attention to the idy of solar heat in 1860. He received a patent om the French government in 1861. In 1864 d 1865 he made valuable inventions in pumping paratus based on the "continual fountain" De Caus, and exhibited also parabolic mirrors th suitable receivers. His studies resulted in 69 in his invention of a mirror of conical form, the focal line of which he placed a blackened etallic vessel covered by a thin, clear glass jar hold the heat which the rays of the sun poured rough its transparent sides upon the vessel. iere he cooked beef à la mode in 1½ hours; tatoes in an hour; baked bread in three-quarters an hour, broiled (roasted) beef in 22 minutes, ving its juice in the bottom of the pot.

In 1868 Ericsson announced that he had con-

structed three small solar engines, upon which he and some others based the claim that he was earlier in his discoveries than Mouchot. But careful investigation must lead any person to award priority both of design and construction to Mouchot.

In October, 1875, he reported to the French Academy of Science an apparatus of which his book presents a full description and figure.

The government assisted him from time to time, and sent him, in 1877, to Algeria for extended observations in this line, which he also reports. On his return they voted him a liberal sum of money to enable him to construct his culminating success, the engine which he exhibited at the Exposition in Paris in 1878.

We give a copy of his own illustration of this great work.

Those of our readers who do not read French will probably have no difficulty in understanding the important features of the apparatus.

The mirror had an opening of about 20 square metres (say a circular opening 13½ feet in diameter). The boiler, 6½ feet long, had a

capacity of about 21 gallons, into which water to the amount of 16 gallons was poured, while the remaining space was left for steam.

Placed in the sun at Trocadero (Paris), September 2, 1878, in half an hour its water was boiling and the pressure of 6 atmospheres was quickly reached. The 29th of September, with a clear sky, at 11.30 A. M., a pressure of 7 atmospheres was attained, and he produced the first block of ice ever made by the heat of the sun. Other most satisfactory achievements followed during that month and the next, in cooking, distilling, pumping, etc., etc. The Exposition awarded him a medal.

FIRST UNITED STATES PATENT.

In the United States, the first patent for solar apparatus was issued March 20, 1877, to John S. Hittell and George W. Deitzler, of San Francisco, Cal. Their patent describes a "concave mirror, with which they throw focalized heat upon a mass of iron or other suitable material

as a reservoir of the heat; a reservoir chambe a heat box, a drying chamber," etc., letting th cold air pass in and then pass out again afte the sun has heated it, applying it then to ordi nary hot-air machinery. Mr. Deitzler took out second patent May 19, 1882, in which he de scribed "a reflecting mirror, straight one way curved the other" — half of a tube or cylinde if you please (what we elsewhere call a cylin drical mirror), and in the line-focus thus forme he placed a tube filled with the material to b heated. In both patents the ordinary method were used to keep the apparatus facing the sun

These gentlemen deserve to be enrolled hig on the walls of the *true* Temple of Fame fo their contributions to the development of sola calorics. Mr. Hittell had previously earned th gratitude of his fellow citizens by his admirab book, "The Resources of California," which di a great deal to acquaint the world with the frui and grain capabilities of the State, and its othe advantages, attracting both immigration an capital to the coast. Mr. Deitzler entered ver practically into the subject, with a mechanica

GRAND GÉNÉRATEUR SOLAIRE INDUSTRIEL

EXPOSÉ

Dans le Parc du Trocadéro

(*Annexe de l'Exposition Algérienne*)

ET RÉCOMPENSE D'UNE MÉDAILLE D'OR

LÉGENDE

M. Secteur permettant, au moyen de la vis *m*, d'incliner l'appareil suivant la latitude du lieu où l'on opère.

N. Mouvement à la cardan permettant, par l'intermediaire des pignons d'angle, de la roue *r* et du secteur vu de profil sur la figure ci-contre, d'orienter l'appareil du lever au coucher du soleil.

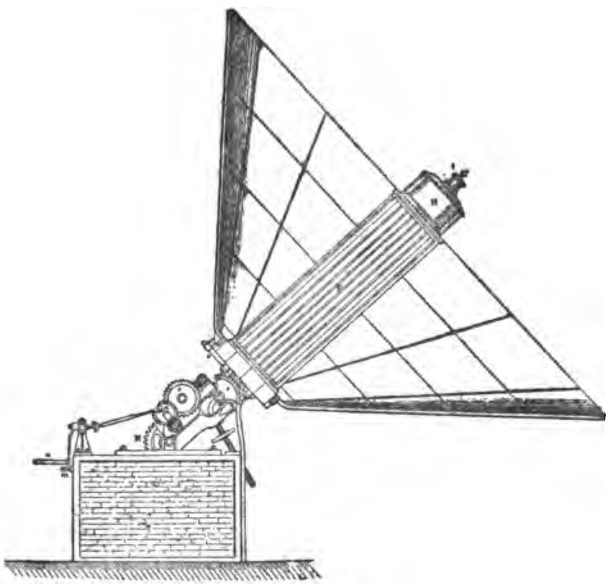
S. Secteur permettant, au moyen de la vis *o*, d'incliner l'appareil suivant l'époque de l'année où l'on expérimente.

F. Chaudière tubulaire entourée du manchon de verre.

H. Dôme de vapeur.

I. Soupape de sûreté.

La vis ci-contre munie d'un volant servait de contreventement à l'appareil une fois placé suivant l'angle de la latitude. Le refléteur composé de fers à T supportant les plaques réfléchissantes était fixé sur la base en fonte de la chaudière. Cette dernière, composée de tubes en fer avait une capacité de 100 litres, 70 pour l'eau, 30 pour la vapeur. Son alimentation se faisait au moyen d'un injecteur.



GRAND GÉNÉRATEUR SOLAIRE INDUSTRIEL
PAR PROF. A. MOUCHOT (1878)

skill and business energy which attracted the attention of a considerable number of men of affairs to this matter.

THE SOLAR HEAT POWER COMPANY OF CALIFORNIA

was formed in 1883, of which Wm. H. Birch, A. F. Knorp, Geo. A. Dickson, Geo. W. Deitzler, and H. C. Biggs were directors, with Oscar Hines secretary, which both expressed and increased general interest in the matter. [See *San Francisco Bulletin,* March 12, 1883.] The death of "General Deitzler" interfered with the success of the company somewhat.

The second patent issued by our government in this department was given April 27, 1880, to James P. Mauzey, of Blackfoot, Montana; whose design was substantially a framework of rectangular form, with mirrors arranged on its (inner) walls, all so placed as to concentrate their rays on the focal point or region, where he put the substance or article to be heated. Of this

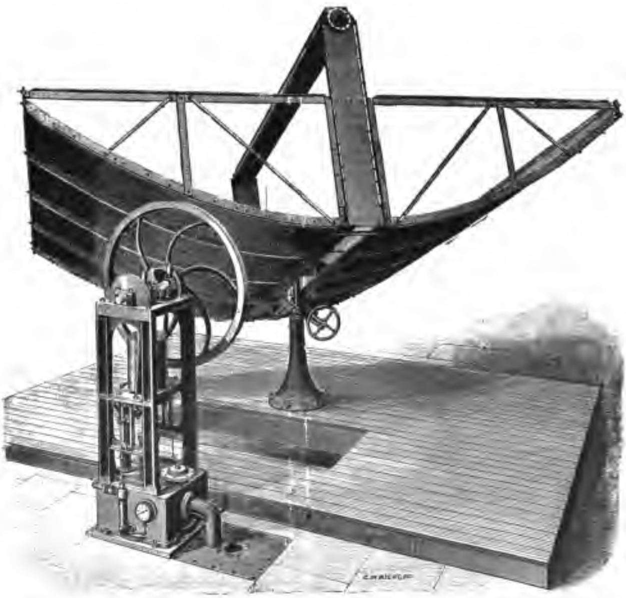
gentleman the writer has failed to learn any particulars. Another patent for solar-heating devices was obtained by Pacific coast men from the British government. Eusebius J. Molera and John C. Cebrian, of San Francisco, Cal., were the persons, and the date of the issue of their patent was October 22, 1880. No special interest attaches to the specific designs they described. Of them and their work the writer is also unable to learn anything; yet they and Mr. Mauzey must not be forgotten in the coming years of triumph which await the cause of solar heat utilization.

In December, 1883, W. Calver, of Washington, D. C., patented a car containing interior reflecting surfaces, which revolved on a circular track, so as to face the sun.

Another name which deserves to be placed high on the roll of the fostering friends of solar enginery is that of Captain John Ericsson, of New York City, the renowned inventor and builder of the *Monitor*. He was a builder of hot-air engines and other mechanical constructions. He made elaborate experiments; invented

an instrument for the measurement of the heat which comes from the sun; also designed a boiler and engine for the operation of machinery by solar heat, a cut of which we reproduce from the *Scientific American* of May 5, 1877, by permission of the publishers. He calculated that "the heat radiated by the sun during nine hours per day, for all the latitudes comprised between the equator and the forty-fifth parallel, corresponds per minute and per square foot of normal surface to 3.5 thermo units of 772 foot pounds. This would give a power of 270.000 foot pounds, or from 8 to 9 horse power on a surface of 100 square feet. The engine illustrated was built on the caloric system, and had run at 420 revolutions per minute, with the sun near the zenith and during fine weather."

By the kindness of Mr. T. M. McDonough, of Montclair, N. J., our attention was called to the following article contributed by Captain Ericsson to *Nature,* and there printed January 3, 1884; reprinted in the *Scientific American* of February 2, 1884, describing his second design.



ERICSSON'S SUN MOTOR, ERECTED AT NEW YORK, 1883

"THE SUN MOTOR AND THE SUN'S TEMPERATURE.

"The annexed illustration represents a perspective view of a sun motor constructed by the writer and put in operation last summer. This mechanical device for utilizing the sun's radiant heat is the result of experiments conducted during a series of twenty years; a succession of experimental machines of similar general design, but varying in detail, having been built during that period. The leading feature of the sun motor is that of concentrating the radiant heat by means of a rectangular trough having a curved bottom lined on the inside with polished plates, so arranged that they reflect the sun's rays toward a cylindrical heater placed longitudinally above the trough. This heater, it is scarcely necessary to state, contains the acting medium, steam or air, employed to transfer the solar energy to the motor; the transfer being effected by means of cylinders provided with pistons and valves resembling those of motive engines of the ordinary type. Practical engineers, as well as

scientists, have demonstrated that solar energy cannot be rendered available for producing motive power, in consequence of the feebleness of solar radiation. The great cost of large reflectors, and the difficulty of producing accurate curvature on a large scale, besides the great amount of labor called for in preventing the polished surface from becoming tarnished, are objections which have been supposed to render direct solar energy practically useless for producing mechanical power.

"The device under consideration overcomes the stated objections by very simple means, as will be seen by the following description. The bottom of the rectangular trough consists of straight wooden staves, supported by iron ribs of parabolic curvature secured to the sides of the trough. On these staves the reflecting plates, consisting of flat window glass silvered on the under side, are fastened. It will be readily understood that the method thus adopted for concentrating the radiant heat does not call for a structure of great accuracy, provided the wooden staves are secured to the iron ribs in such a

ERICSSON'S SOLAR CALORIC ENGINE

position that the silvered plates attached to the same reflect the solar rays toward the heater. Fig. 2 represents a transverse section of the latter, part of the bottom of the trough, and sections of the reflecting plates, the direct and reflected solar rays being indicated by vertical and diagonal lines.

"Referring to the illustration, it will be seen that the trough, 11 feet long and 16 feet broad, including a parallel opening in the bottom, 12 inches wide, is sustained by a light truss attached to each end, the heater being supported by vertical plates secured to the truss. The heater is 6¼ inches in diameter, 11 feet long, exposing 130 x 9.8—1,274 superficial inches to the action of the reflected solar rays. The reflecting plates, each 3 inches wide and 26 inches long, intercept a sunbeam of 130 x 180—23,400 square inch section. The trough is supported by a central pivot, round which it revolves. The change of inclination is effected by means of a horizontal axle — concealed by the trough — the entire mass being so accurately balanced that a pull of 5 pounds applied at the extremity enables a per-

son to change the inclination or cause the whole to revolve. A single revolution of the motive engine develops more power than needed to turn the trough and regulate its inclination so as to face the sun during a day's operation.

"The motor shown by the illustration is a steam-engine, the working cylinder being 6 inches in diameter with 8 inches stroke. The piston-rod, passing through the bottom of the cylinder, operates a force-pump of 5 inches diameter. By means of an ordinary cross-head secured to the piston-rod below the steam cylinder, and by ordinary connecting rods, motion is imparted to a crank shaft and fly wheel, applied at the top of the engine frame; the object of this arrangement being that of showing the capability of the engine to work either pumps or mills. It should be noticed that the flexible steam-pipe employed to convey the steam to the engine, as well as the steam-chamber attached to the upper end of the heater, have been excluded in the illustration. The average speed of the engine during the trials last summer was 120 turns per minute, the absolute pressure on the working piston being

35 pounds per square inch. The steam was worked expansively in the ratio of 1 to 3, with a nearly perfect vacuum kept up in the condenser enclosed in the pedestal which supports the engine frame.

"In view of the foregoing, experts need not be told that the sun motor can be carried out on a sufficient scale to benefit very materially the sunburnt regions of our planet.

"With reference to solar temperature, the power developed by the sun motor establishes relations between diffusion and energy of solar radiation, which show that Newton's estimate of solar temperature must be accepted.

"The following demonstration, based on the foregoing particulars, will be readily comprehended. The area of a sphere whose radius is equal to the earth's mean distance from the sun being to the area of the latter as $214.5^2:1$, while the reflector of the solar motor intercepts a sunbeam of 23,400 square inches section, it follows that the reflector will receive the heat developed by 0.508 square inch of the solar surface. Hence, as the heater of the motor contains

74 square inches, we establish the fact that the lected solar rays, acting on the same, are *fused* in the ratio of 1,274:0.508—2,507:1. actice has now shown that, notwithstanding s extreme diffusion, the radiant energy trans- tted to the reflector, by the sun, is capable of parting a temperature to the heater of 520° F. ove that of the atmosphere. The practical monstration thus furnished by the sun motor ables us to determine with sufficient exactness : minimum temperature of the solar surface. also enables us to prove that the calculations .de by certain French scientists, indicating it solar temperature does not exceed the nperatures produced in the laboratory, are olly erroneous. Had Pouillet known that solar liation, after suffering a *two thousand five ndred and sevenfold* diffusion, retains a radi- : energy of 520° F., he would not have erted that the temperature of the solar surface 1,760° C. Accepting Newton's law that 'the nperature is as the density of the rays,' the nperature imparted to the heater of the sun tor proves that the temperature of the solar

surface cannot be less than 520° x 2,507—1,303,-640° F. Let us bear in mind that, while attempts have been made to establish a much lower temperature than Newton's estimate, no demonstration whatever has yet been produced tending to *prove* that the said law is unsound. On the contrary, the most careful investigations show that the temperature produced by radiant heat emanating from incandescent spherical bodies diminishes inversely as the *diffusion* of the heat rays. Again, the writer has proved by his vacuum actinometer, enclosed in a vessel maintained at a constant temperature during the observations, that for equal zenith distance the intensity of solar radiation at midsummer is 5.48° F. less than during the winter solstice. This diminution of the sun's radiant heat in aphelion, it will be found, corresponds within 0.40° of the temperature which Newton's law demands. It is proposed to discuss this branch of the subject more fully on a future occasion.

"The operation of the sun motor, it will be well to add, furnishes another proof in support of Newton's assumption that the energy increases

as the *density* of the rays. The foregoing explanation concerning the reflection of the rays — see Fig. 2 — shows that no augmentation of temperature takes place during their transmission from the reflector to the heater. Yet we find that an increase of the number of reflecting plates increases proportionably the power of the motor. Considering that the parallelism of the rays absolutely prevents augmentation of temperature during the transmission, it will be asked: What causes the observed increase of mechanical power? Obviously, the energy produced by the increased *density* of the rays acting on the heater. The truth of the Newtonian doctrine, that the energy increases as the density of the rays, has thus been verified by a practical test which cannot be questioned.

"It is scarcely necessary to observe that our computation of temperature — 1,303.640° F. — does not show maximum solar intensity, the following points, besides atmospheric absorption, not having been considered: (1) The diminution of energy attending the passage of the heat rays through the substance of the reflecting plates;

(2) the diminution consequent on the great amount of heat radiated by the blackened surface of the heater; (3) the diminution of temperature in the heater caused by convection.

"J. ERICSSON."

After Mr. Ericsson's death, there was considerable disappointment felt by his admirers that no complete development of his inventions in this department was found among his effects; it would appear that advancing years prevented that great concentration of his faculties on this point, which had made him so successful in the building of the *Monitor,* and which might have wrought greater success in the arts of peace had he lived to develop all he had planned.

INDIA OFFERS A FINE FIELD FOR THE UTILIZATION OF SOLAR HEAT.

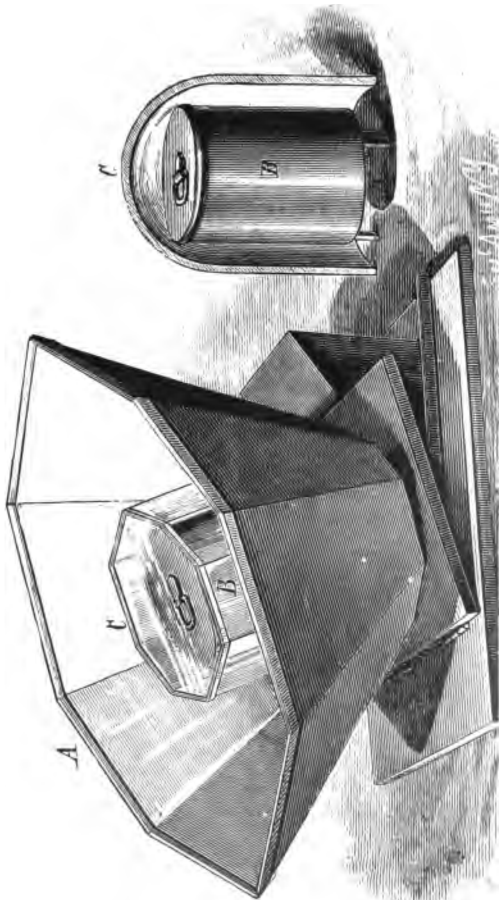
Mr. W. Adams, an English resident of Bombay, India, made very diligent study of this subject, and developed an apparatus for which he obtained a patent. A public trial of his invention

was made at Bombay in presence of officials and representatives of the press and others. In *The Times* a full account of the exhibition was presented, and this was reprinted in the *Scientific American* of June 5, 1878; two weeks later the latter paper published a letter from Mr. Adams, detailing many interesting facts about the matter, and presenting a cut of the apparatus. We reprint these by permission of Messrs. Munn & Co.

"COOKING BY SOLAR HEAT.

"*To the Editor of the Scientific American:*

"I send you a short account of my experiments, made in Bombay, on the utilization of solar heat for cooking. The accompanying engraving will give an idea of the principle of the cooking apparatus. It consists of a conical reflector, A, made of wood and lined with common silvered sheet glass. Inside there is placed a copper cylindrical vessel, B, covered by a glass cover, C. The cooking vessel is raised about four inches from the bottom, and the glass cover is five inches longer than the vessel, and two



inches wider, which leaves an interval of four inches of hot air under the boiler, and one inch all round and at the top. The wedge under the apparatus is to keep it inclined, so that the rays of the sun may fall perpendicularly on the boiler. Glass being diathermanous to the direct or reflected rays of the sun, and non-diathermanous to obscure heat, the rays penetrate the glass, and, striking on the vessel, become transformed into obscure heat, when they are retained by the glass. The glass cover over the boiler is made octagonal, because, in that form, common window glass can be used. Of course a glass dome, such as is used for covering clocks or statuettes, would be better, and, equally, of course, a copper reflector electroplated with silver would be better than my reflector; but both of these articles are made octagonal in order that cheap material may be employed. The position of the apparatus requires to be changed about every half-hour, to face the sun in its apparent course from east to west.

"The rations of seven soldiers, consisting of meat and vegetables, are thoroughly cooked by

it in two hours, in January, the coldest month of the year in Bombay, and the men declare the food to be cooked much better than in the ordinary manner. Several people in Bombay and in the Deccan have tried it, and always with success. If the steam be retained, the dish is a stew or a boil; if it be allowed to escape, the food is baked.

"The reflector is two feet four inches in diameter. The intensity of the heat is increased by increasing the diameter of the reflector. One advantage of this apparatus is that the food will keep hot for a long time after the apparatus has been withdrawn from the solar rays. I withdrew it at 4 P. M., brought it into a room, and threw a railway rug over it. At 8 P. M., when it was uncovered, the metal vessel was too hot to be handled by the bare hand. I have a letter from a surgeon-general in the service, which informs me that he cooked a leg of mutton in it, and that it 'kept hot for four hours' after having been removed from the air.

"I am getting one made six feet in diameter, which will differ from that represented in the

engraving by consisting of fourteen flat glasses instead of eight, and by having an angle of 45° until it is on a level with the middle of the vessel, and thence upward an angle of about 60°, by which arrangement the whole of the rays reflected from the silvered glass will fall on the lower half. Besides cooking food, I am making a series of experiments for heating steam-boilers by concentrating the rays of the sun upon them.

"For this purpose I use a combination of flat mirrors, of common sheet glass, silvered, fixed in rectangular frames so as to concentrate the solar rays to a focus at a distance of 20 feet. The focus is about 2 feet in diameter. The plan is on the same principle as that of Archimedes, by which he burned the Roman fleet, which, under Marcellus, was blockading Syracuse — the same plan as that suggested by Anthemius of Tralles in the problems by which he proved the exploit of Archimedes to be possible; and as that suggested by Kircher, and in 1747 adopted by Buffon. With 72 pieces of silvered sheet glass, each 15 x 10½ inches, at midday, in the month of May, a focus was formed, at a distance

of 20 feet, of a temperature above 1,088° F. I arrived at that estimate as follows: 18 glasses raised the mercury in the thermometer to 360°; 36 glasses raised it to over 644°, when the mercury entered into ebullition, and consequently any further rise could not be registered. The ebullition of the mercury was very violent. Placing the temperature produced by the 36 glasses at 644°, the boiling point of mercury, and deducting 100° as the initial temperature of the atmosphere (the thermometer was in the shade), there remain 544° produced by 36 glasses. The focus from the remaining 36 glasses was then added, making 72 glasses; and I think it may be inferred that the temperature was then above 1,088°. Every kind of wood placed in this focus was instantly ignited, without being, as in Buffon's experiment, previously smeared with tar and shreds of wool. A solid cylinder of water, 18x8 inches, contained in a vertical copper vessel, provided with a steam-pipe, was then placed in the focus, and it boiled in exactly 20 minutes. The ebullition was exceedingly violent. In January last I made an-

other experiment with 198 glasses, each 15x10½ inches, fixed in 10 rectangular frames. A copper boiler containing 9 gallons of cold water was placed in the focus at 9.25 A. M. It commenced to boil in exactly 30 minutes. It was allowed to boil for exactly 1 hour, and at 10.55 the focus was turned off, when 3¾ gallons of water were found to have been evaporated.

"My next experiment will be made with about 500 of these glasses, fixed in 20 rectangular frames, each 6 feet by about 4 feet. The focus will be about 2 feet in diameter, and (according to the calculation made on the basis of the results of the experiment with 72 glasses) the temperature will be over 7,616° F. The objects of that experiment will be to ascertain how soon after sunrise the water can be provoked to boil, the pressure that can be obtained in a given period, and the quantity of water that can be vaporized in a given time, Other experiments will be made, such as exposing different metals to the focus, etc. The boiler that will be used on that occasion is a vertical boiler, 2 feet 7 inches high and 16 inches in diameter, with an annular cylinder of

water 3 inches in diameter up to half its height. It is made of beaten copper, ¼ inch thick, which will stand any pressure that can be produced in a boiler of those dimensions. It is provided with a steam-pipe, a steam-gauge, and a safety valve, and with no other fittings. The 20 frames will stand in two rows of 10 each, the second row on a platform 6 feet 6 inches high, forming a segment of a circle of 40 feet in diameter.

"As there is no limit whatever to the number of these mirrors that can be used at once, there is none to the intensity of heat that can be produced, and consequently no limit to the force of the steam that can be generated. The cost of the reflecting material is next to nothing, and it is almost everlasting. There is no mechanical difficulty in keeping the focus on the boiler from soon after sunrise to a little before sunset.

"I am aware of the force of the objection that the solar rays are sometimes intercepted by clouds, even in India; but as an auxiliary to the ordinary boilers, I believe that solar heat could be used so as to save at least 25 per cent. of coal throughout the year by my plan. As

coal in the seaports of India is never under 30 shillings per ton, and double that rate in the interior, such a saving would be exceedingly important. There are many other purposes to which it could be applied besides driving steam machinery or cooking food, such as distilling and rectifying spirits, etc. At Aden, for example, the sun always shines, and potable water is only obtained by distilling it from salt water.

"I shall be very glad to have any expression from your readers upon the subject, especially upon the result of the experiment that I have described. W. ADAMS.

"*Bombay, India.*"

FRANCE CONTINUES MOUCHOT'S WORK.

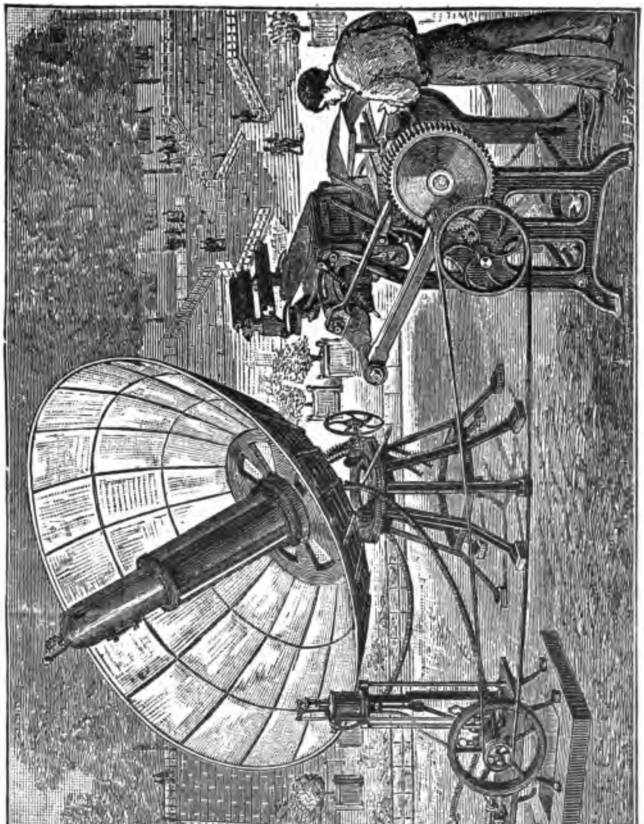
The following very interesting article was translated and reprinted in the *Scientific American* of May 13, 1882, from that valuable journal, *La Nature*. We reprint the article by permission, reproducing, also, the cut which illustrated the original article. It would be of great interest to us to learn more about the labors of M. Pifre,

who thus carried out ideas of M. Mouchot, and elaborated new applications of his own.

"PRINTING BY SOLAR HEAT.

"Our readers already know of Mr. Mouchot's curious solar generators, and of the remarkable experiments that have been performed by that ingenious physicist for the purpose of turning to account that immense reservoir of heat and motive power, the sun. Mr. Abel Pifre, an engineer, has recently taken up the labors of Mr. Mouchot, and has constructed upon the same principles as those employed by his predecessor as the base of his apparatus, an *insolator,* which gathers the heat of the solar rays in the focus of a mirror, and converts it into mechanical motion.

"On the occasion of the *fête* of the 'Union Française de la Jeunesse,' which occurred Sunday, August 6, 1882, in the Garden of the Tuileries at Paris, there was witnessed a remarkable experiment with Mr. Pifre's latest improvements in the solar generator.



"There was set up on this occasion in the garden, near the large reservoir, at the foot of the Jeu de Paume stairs, an insolator that measured 3.5 metres in diameter at the opening of the reflector. The steam obtained in the boiler carried by the reflector at its focus was utilized by a small verical motor, of 30 kilogrammetres power, which actuated a Marinoni printing-press. Although the sun was not very hot, and its radiation was interfered with by frequent clouds, the press was able to work with regularity between one and five o'clock in the afternoon, and to print on an average five hundred copies per hour of a journal specially composed for the occasion, and entitled *Soleil-Journal* (*Sun Journal*). This is not a revolution in the art of printing, but the result is sufficient to allow us to judge of the services that *insolators* might render in latitudes submitted to a radiation at once more active and constant.

"We could not allow this splendid experiment to pass without preserving a souvenir of it. Our engraving faithfully represents the arrangements adopted. The Pifre insolator is seen in

the centre of the cut, with its large parabolic mirror; the engine actuated by it is figured at its side; while in the foreground to the right is seen the Marinoni press printing the journal. It seems evident to us that in hot countries the use of *heliodynamics* ought sometimes to prove effective and economical." — *La Nature.*

May 13, 1882, there appeared in the *American* an account of an invention wrought out by Prof. E. S. Morse, of Salem, Mass., for "Utilizing the Sun's Rays in Warming Houses." "It consists of a surface of blackened slate under glass, fixed to the sunny side of a house with vents in the walls, so arranged that the cold air of a room is let out at the bottom of the slate and forced in again at the top by the ascending heated column between the slate and the glass." The statement was made that the inventor's house at Salem was then heated by the means described in fine weather. The idea thus brought forward has been met within recent years by some very practical devices, which are now on the market.

In the issue of the *American* of December 30,

1882, an account is given of the "solar cannon of the Palais Royal in Paris, France, which is fired by the heat of the sun at noon, concentrated by means of a burning glass, falling on the powder priming of the cannon." The device is very ancient; a traveller, Néel, writing in 1751, describes it. The same journal, in the number for August 18, 1883, contained an appeal, written by one who signed only the letter "A," intended to awaken the public to a sense of the value of solar heat utilization. He called attention, especially, to the importance of the invention and construction of lenses of great size at moderate cost, reminding the reader that the concentration of solar heat would not require anything like the exact and achromatic degree of nicety which astronomical work demands.

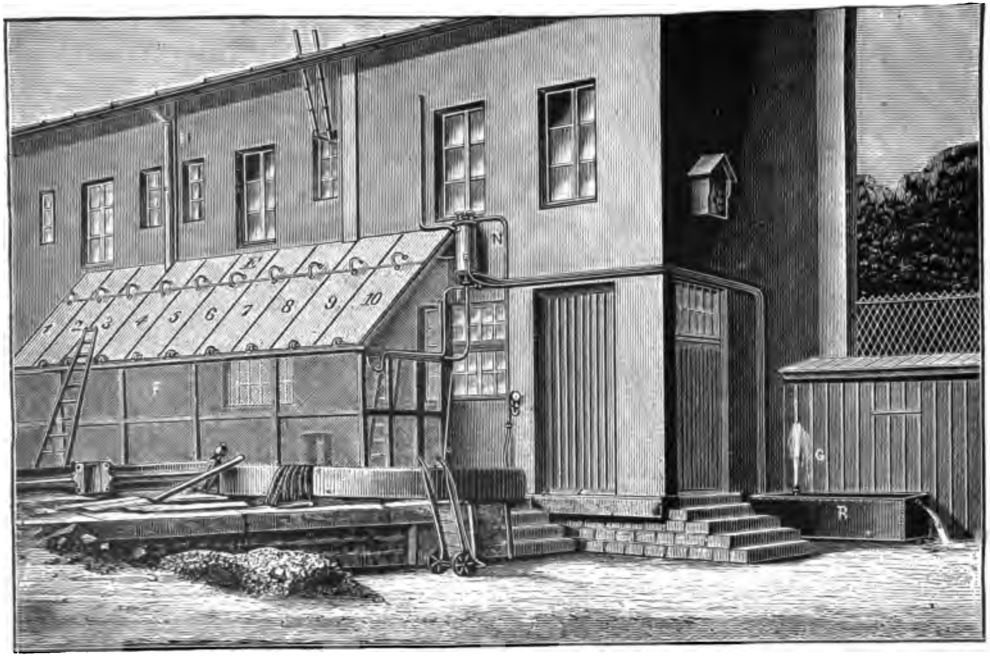
A contribution of no slight consequence to this subject appeared in the *Scientific American* October 3, 1885, translated from *La Nature*. We copy the article and illustration by permission.

"THE UTILIZATION OF SOLAR HEAT FOR THE ELEVATION OF WATER.

"This article will treat of the combined application of two natural forces to the elevation of water. These forces are: first, the heat of the atmosphere; and second, the comparatively low temperature of the water to be raised.

"The accompanying drawing shows the general arrangement of an apparatus worked on this principle. This apparatus has been built at Auteuil, where it operates very well, although our climate is not favorable to the operation of such a device.

"F is a small building covered by a roof, E, which is exposed to the south, and this roof is formed of ten metallic plates, which are numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Each of these plates consists of two sheets of iron riveted together on all their edges, and separated slightly by filling pieces. Each plate thus constitutes a water-tight receptacle, in which a volatile liquid can be held. Various liquids can be used, but I prefer a solution of ammonia. Under the influ-



THE UTILIZATION OF SOLAR HEAT FOR THE ELEVATION OF WATER.

ence of atmospheric heat, the solution emits vapors, and said vapors or gases escape through tubes, one of which is provided for each plate, and are conducted to the receptacle N. Any liquid which may have been carried along by the gas is taken back to the plates by a tube. By another tube the gas escapes from the vessel, N. This gas has a pressure of 1, 2, or 3 atmospheres, according to the work which is to be done. It is conducted through a tube to a hollow sphere, which is placed in the well or tank from which the water is to be elevated. This sphere contains a rubber diaphragm, which can attach itself to either half of the sphere.

"Let us suppose, for instance, that the sphere is full of water; the rubber diaphragm, consequently, will rest against the upper half or hemisphere. If, now, the pressure of the ammonia gas is brought to bear on the diaphragm, it will be forced to rest on the lower hemisphere; but in order to do this, the diaphragm must eject the water which fills the sphere. This causes the formation of a jet of water, as shown above the tank, R, near the letter G. But the gas must

be driven from the sphere after it has been emptied of water, so that the operation may be renewed.

"This is accomplished in the following manner: In the centre of the diaphragm a float is inserted, which carries a rod by which a slide is actuated. One of the apertures in this slide coincides with the gas inlet, and the other with the outlet. When the diaphragm rests on the upper hemisphere the inlet is opened, and the water escapes; when it moves toward the lower hemisphere the inlet is closed, the outlet is opened, the sphere is filled with water again, and so on.

"This would complete the operation if the ammonia gas did not cost anything, but as it is expensive it must be used over and over indefinitely. Here we are aided by the low temperature of the water, which is made to pass through a serpentine pipe contained in a water-tight vessel containing part of the ammonia solution used. The solution is cooled by the water in the pipe, and is ready to absorb ammonia. Then, as soon as the outlet is opened, the ammonia gas con-

ducted into it is absorbed, the pressure which was exerted in the sphere is removed, and water can again enter the sphere.

"A final precaution is taken, which is to attach a little pump to the float, by means of which the ammonia solution can be pumped back into the roof, E.

"The apparatus at Auteuil raises over 300 gallons of water per hour. In warm countries the same apparatus would raise 792 gallons a distance of 65 feet. The calculation of the results to be obtained by this apparatus is based on the following considerations:

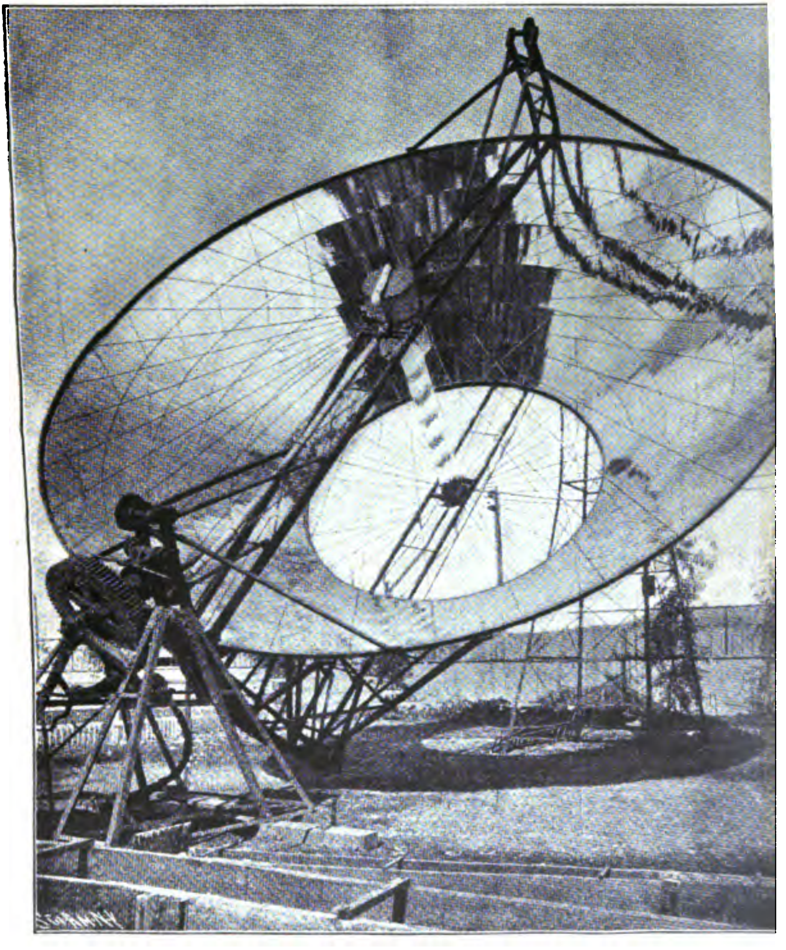
"A sheet of metal one yard square absorbs 11 calories for a difference of one degree. Each plate which has a surface of 4 square yards absorbs 44 calories per hour. If there is a difference of 6 degrees, 264 calories will be taken from the atmosphere every hour; and by combining this quantity of heat with the cooling action of the water, it is easy, by the difference of tension produced, to obtain an inexpensive force for raising water.

"This apparatus differs from the numerous

devices by which attempts have been made to utilize solar heat by means of the Archimedean mirror, by which only secondary heat is obtained. It is not necessary to concentrate the heat by metallic or other mirrors; the atmospheric heat is the basis of the operation, and all roofs exposed to the sun can be used for this purpose. In this manner a valuable motive power can be obtained in warm countries without loss of room. Generating plates, such as we have described, can be applied to any roof, and if we consider that with only ten such plates 792 gallons can be raised 65 feet per hour, we can easily understand that a great elevating power can be obtained by increasing the number of plates."

THE PASADENA PUMPING-ENGINE.

Prof. Charles F. Holder, of California, widely famous for his learning and his writings, contributed to the *Scientific American* of March 16, 1901, a very readable article upon solar motors. He went over the history of the subject to some extent; mentioned a "burning mirror,"



THE PASADENA PUMPING-ENGINE
Front View

which was made by a Frenchman named Villette, 4 feet in diameter, at whose focus the heat was so intense that cast-iron was melted there in sixteen seconds; that an Englishman named Parker built a lens about 3 feet in diameter, at the focus of which a cube of cast iron was melted in three seconds, and a block of granite fused in one minute. After other instances and discussion, he went on to describe a motor which had been builded at the Ostrich Farm in South Pasadena, California.

"The machine is exhibited at the Ostrich Farm, and has attracted the attention of a vast number of people, especially as Southern California is now thronged with tourists. In appearance the motor resembles a huge disk of glass, and at a distance might be taken for a windmill of some kind; but the disk is a reflector 33 feet 6 inches in diameter on top, and 15 feet on the bottom. The inner surface is made up of 1,788 small mirrors, all arranged so that they can concentrate the sun upon the central or focal point. Here, as shown in the accompanying illustration, is suspended the boiler, which is 13 feet 6 inches

in length, and holds 100 gallons of water, leaving 8 cubic feet for steam.

"At the time of the writer's visit to the farm, the motor was the subject of no little comment, and the attendant stated, confidentially, that some of the questions were remarkable. One man assumed that it had something to do with the incubation of the ostrich eggs; and many asked what made it go, being unable to understand or appreciate the idea. The motor is attractive in appearance, built lightly, supported by seemingly delicate shafts, though in reality strong enough to resist a wind pressure of one hundred miles an hour. The reflector must face the sun exactly, and, as heavy as it is, weighing tons, it can be easily moved. It stands, after the fashion of the telescope, upon an equatorial mounting, the axis being north and south. The reflector follows the sun, regulated by a clock, the work being automatic, as, in fact, is everything about it. The true focus is shown by an indicator; and in about an hour after it is adjusted the boiler is seen to have attained a white heat, and the steam-gauge registers 150 pounds. The steam is car-

THE PASADENA PUMPING-ENGINE
Side View

ried from the suspended boiler to the engine in a flexible phosphor-bronze tube, and returns again from the condenser to the boiler in the form of water, so that the boiler is kept automatically full. The engine is oiled automatically, and when the disk is once turned, facing the sun, it runs all day as independent of an engineer as does a windmill.

"The amount of heat concentrated in the boiler by the seventeen hundred and odd mirrors cannot be realized, as nothing can be seen but a small cloud of escaping steam; but should a man climb upon the disk and attempt to cross it, he would be literally burned to a crisp in a few seconds. Copper is melted in a short time here, and a pole of wood thrust into the magic circle flames up like a match. That the motor is a success is seen by the work that it is doing — pumping water from a well, illustrating the possibilities of cheap irrigation by lifting up 1,400 gallons per minute — equal to 155 miner's inches. Up to the present time, the motor has produced results equal to about ten horse-power, but fifteen horse-power is claimed for it.

"This motor is the result of a number of experiments by a band of Boston capitalists. One of the first productions was a silver reflector, which cost many thousands of dollars, but was abandoned. The next was modelled after the Ericsson machine of 1884; but it was a failure. A third was erected at Longwood, proving also a failure. A fourth attempt was made, this time at Denver, Colo., which was fairly successful, doing one-half of the work since performed by the Pasadena model. This latter was at length produced, and found to be a success.

. . . .

"No invention of modern times has given such an impetus to the development of arid lands as the solar motor, and it has been visited by many interested in the question. The development of Southern California has been seriously hindered by the lack of fuel, the country being dry and barren in localities where rich mines are known to exist. The country is cloudless for months, — in every sense the land for solar motors, as water underlies the surface almost everywhere, and, when pumped up and sent out upon

the soil, the region ceases to be a desert, and can be made to blossom as the rose."

A WORD FROM AN AMERICAN IN INDIA.

June 15, 1901, there appeared in the *Scientific American* a letter from Rev. Walter T. Scudder, an American missionary at Vellere, in the presidency of Madras, India, which should be noted here. He seems not to have known of the experiments and successes of Mr. Adams at Bombay in a former year, nor of other historical illustrations of solar heat in service; he had, however, read the article just quoted from Professor Holder, and fully endorsed its reasonings, and accepted its testimony from the standpoint of a resident in India. He gave the results of some experiments he had made in testing the actual heat of the rays of the sun by the use of ordinary thermometers. Hanging one instrument in the open air, where the sun shone full upon it, he placed another in a cardboard box, covered with glass, through which the rays of the sun were admitted, the heated air being en-

closed by the box. April 7, 1901, he found that the former thermometer indicated 126° F., and the latter 157°; five days later, in a similar trial, he obtained 127° and 159°. He thus demonstrated the fact that the heat of the sun may be economized by sheltering and accumulating the rays. This fact might have been deduced from the common practice of people in cold countries of using double windows for the purpose of economizing fuel and keeping part of the heat of the sun when it comes upon them. M. Mouchot, too, used this principle in the glass cover which he placed over his boiler at the focus of his reflector. The idea is capable of very large application.

CHAPTER II.

SOME TECHNICAL STUDY OF THE SUBJECT.

LET me ask you to note carefully at the outset these two points first, that this treatise does not concern itself at all with the nature of the sun, or its rays; the orb may be of flame or of ice; the rays may be dependent on or affected by local conditions at the sun, or by the quality of our atmosphere, or both. None of these particulars, these questions, affect the practical matter we have in hand. We find sunshine coming upon us; we learn from experience that we can get heat from the rays as they fall, and can combine the force of a number of rays in a beam of increased intensity.

Our problems are along these two lines: How can we best receive and accumulate the heat

which the sun brings to us? The "technical study" here attempted is most practical in its quality; intended for the man of the farm and the shop quite as much as the man of the school or the laboratory. A future stage of the art will necessarily take up deep questions of theory for the higher development of the subject; but now and always the chiefly important side of the matter is the practical. How can we get and use the largest amount of solar heat?

And, second, the manner of treatment here given to the problems in hand is one which aims to inform the man who has no technical library at hand, to aid the ranchman and the prospector in devising offhand appliances, as well as to help the educated and skilled artisan and manufacturer along their paths, by a few blunt, crude hints and by the suggestive force of the historical accounts herein presented.

NOMENCLATURE.

What are the proper terms to be used in describing the subject of this discussion?

The writer selected as the title of his former work the phrase, "*Solar Enginery*," intending to include all appliances for the collection and use of the heat of the sun, whether a simple heat-box or a steam-engine, maintained by solar caloric. Some objection was made by critics on the ground that the terms might apply equally well to a study of the motion of the sun and its satellites; and because the furnace heated by solar rays is hardly an "engine." *Solar Calorics* is a correct expression for a treatise on the nature and laws of the heat derived from the sun; but is not suggestive of practical utilities. "*The Utilization of Solar Heat*" is a cumbrous phrase, well enough for the index to patents, but not popular in its sound. The well-known term of the schools, *Thermo-dynamics,* would be a good title, but it has so broad a meaning that it does not confine the subject to the limits we have given ourselves; *Helio-thermo-dynamics* (*helios,* the sun; *therme,* heat; and *dunamis,* power) is the precise word for us; only it would not attract the average reader; and this book is made for the every-day man, the unprofessional, prac-

tical person, who has a clearer idea of English than of the Greek language, from which the scientific terms have been customarily drawn. *Solar Heat: Its Practical Applications,* is a title which carries its notion to any reader.

PREMISES.

1. The first of the principles to be stated is this: We have no power to increase or diminish the actual heat which comes to us from the sun at any time; the regulation of that heat is altogether superior to us, depending upon the state of the atmosphere, the wind, dust, clouds, fog, or other things over which we can never acquire any control; we can simply take what comes. There is no such thing as making a greater fire under our boilers, raising the temperature by skilful manipulation of the fire, except by methods of a secondary sort mentioned below.

2. We are able, however, to keep what we get; to fend off winds from our apparatus, to guard our machinery from dust by glass coverings, small or large, movable or stationary, as the

case may demand; we can use means, in case it seems best, to keep our articles or surfaces to be heated facing the sun throughout the day, so as to avail ourselves of all that comes our way; and we can select such localities as are most favorable in all respects for the business. We are also able, by various methods, to connect as many furnaces or engines as we wish, so that the heat of each may contribute to a total result far larger than could be attained by a single apparatus; and we may store up the heat and the power obtained from it for use at some other time or place.

3. While the rays of the sun come to us in parallel lines with a uniform temperature on either hand, and would heat every part of an exposed surface as hot as any other, the laws of heat rays are those of undulation or wave motion in general, the same as those of a ball, thrown on a floor, or a beam of light falling on a table, or a sound-wave reaching a listener. These rays may, therefore, be gathered together, made to unite, as if they became one denser, stronger, hotter ray, so that the temperature of

the condensed rays will be raised in proportion to the number of rays blended; and we can thus cause the heat to increase to any degree our apparatus can be enlarged. By secondary means, then, we can secure a hotter fire in our solar furnace than there is in the open air or on a plain surface. And the art of solar enginery is a reaching after the best means of thus taking, guarding, uniting, and directing these gathered rays for domestic and industrial uses.

The subject has four natural divisions: (A) The Reception of Solar Rays, (B) The Reflection of Solar Rays, (C) The Refraction of Solar Rays, (D) The Application of Solar Heat.

(A) The Reception of Solar Rays. First of all, the article which we desire to heat must be placed directly in the path of the beams of the sun, at right angles to that path. Almost any material has some tendency to refuse admission to the heat of the sun, or, as we say, to reflect away part of what falls upon it; therefore, we must place it so that the rays shall have the best opportunity to enter its very substance. The best color for the article or receptacle is black, and

that free from any sheen or gloss or polish whatever. It is an advantage if the surface be rough, porous, or provided with openings of some kind into which the rays can enter and be lost, so to speak. The receptacle may be furnished with a glass cover, which will admit all the rays (or nearly all), and will hold them back from escaping from the surface after it has become hot. Such protection is particularly important in the windy, dusty regions, where most solar machines must be located. Glass houses — like botanical conservatories — may be built for this purpose, or " sash-beds " or bell-glass coverings may meet the case sometimes.

The article or receptacle to be heated may remain stationary or be swung around at the same speed as the sun, keeping its face toward that orb all the day. Which course is the better will depend upon the nature of the substance to be heated and the use to be made of the heat. Many cases will occur where enough caloric will be obtained by simple "*helio-stats,*" *i. e.* stationary furnaces or ovens. Even water-raising apparatus has been made successful in this way [see

the Auteuil experiment]. There is a large field for investigation and invention here.

But in most cases the article or receptacle must be made to turn as the sun (apparently) turns. Machinery must be used which will cause the structure to revolve as fast as the sun moves. As astronomers have "orienting" machinery to keep their telescopes in the path of the stars, so we must have gear to keep the solar furnace "in the eye of the sun." Two movements are to be regarded; the daily motion across the meridian, or in a westerly course, and the continual change of the path of the sun to a more northerly or southerly position, astronomically speaking. That is to say, during six months the path of the sun is higher above the horizon each day till it reaches its highest, hottest, midsummer altitude; then, during the next six months, the path is daily lower and lower till the lowest, coldest, midwinter altitude is reached. (This statement is entirely unscientific in form, but substantially accurate.)

Our apparatus, for this reason, must be so constructed as to change its path daily, either

automatically or by the hand of an attendant, if we would secure absolutely exact reception of the rays. But the problem is easy, since a simple turning over from left to right (east to west) of a structure lying in the meridian, and a daily change of the elevation of the northern end of the apparatus is all that is needful. Any man of ordinary intelligence can practically locate the meridian, *i. e.* the true north and south line, by driving two stakes at night in the direction of the North Star;[1] and the latitude of the place, subtracted from 90°, gives the highest degree of altitude that the sun will reach at that point. Nature has provided some admirable localities for this business in hillsides that slope toward the south; and apparatus may there be placed at an angle midway of the local range of altitude

[1] Strictly speaking, the North Star is not "fixed." It has a rotary motion in an orbit of what we may practically call very narrow limits. To get the *precise* meridian, it is necessary to make a series of observations upon the pole-star so as to get the extreme east and west positions of the star and their central or average position. But for ordinary solar heating apparatus the line established by a single observation will be sufficiently near the true meridian.

during the season or period when the apparatus is to be most used; and it will then require very little change from day to day in that respect. As, at a place in latitude 39°, the receiver may be located on a slope which has an inclination of 39° 30 min.; because the lowest noon altitude of the sun being 23° less than its highest, and the middle point 11° and 30 min. below the highest; subtracting the latitude from 90, we have 51° as the highest altitude; 23° below that is 28° as the lowest; and 39° 30 min. as the medium.

THE REFLECTION OF SOLAR HEAT.

(B) The rays of the sun may be brought to a focus, gathered into a knot, directed to one spot, made to combine their energy on a point. (See Ericsson's discussion of this subject, page 56). Although we cannot increase the heat of a ray, we can increase the temperature of a spot on which a number of rays thus unite. This is done, sometimes by reflection, *i. e.* by bending the rays from their course; if they strike on a smooth, light surface, into which they cannot enter, or which

they have more tendency to turn away from than to penetrate, they will be bent away in a new direction. The course they take will depend upon the course in which they came; as the geometrical statement is, "The angle of reflection is equal to that of incidence."

We can, then, construct and arrange our reflecting substances in such forms as will bring these newly directed rays of solar heat into our service most advantageously.

The simplest form is a Plane Mirror (Fig. 1). This does not converge the rays at all, but throws them upon the exposed surface in a mass, which will be shaped exactly like the area of the mirror if they are reflected back in the precise direction from which they came; but, if they are thrown to one side, the shape of the mass will be changed according to the angle of reflection, taking the form of a parallelogram whose shorter diameter will be reduced as the plane of the reflector and that of the incident rays approach one another, till it becomes almost a mere line. An indefinite number of rays may be *massed* by plane mirrors, although not strictly concentrated.

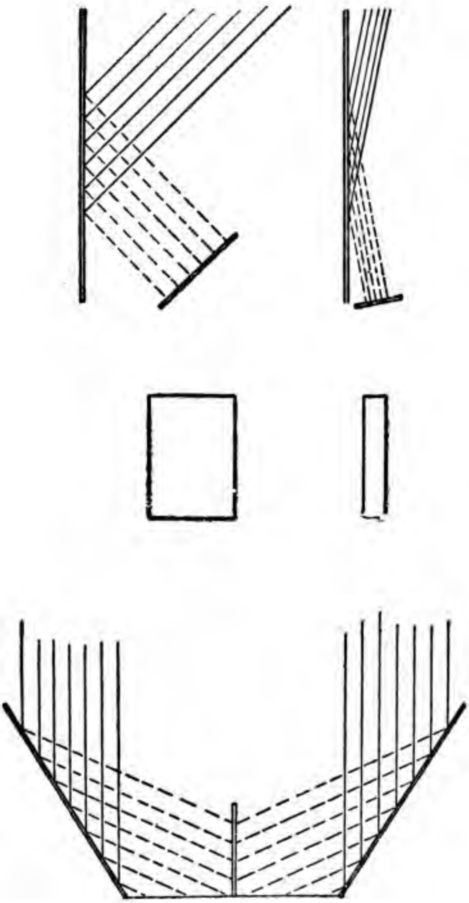


FIGURE I

If we take a plane mirror and bend it in a cylindrical form, we may bring the rays to a line, more or less accurately according to the curvature. A parabolic form will secure the closest approximation to this result (Fig. 2). A pipe, or several parallel pipes, may be heated by this means to a temperature depending on the width of the mirror and the perfection of the reflecting substance. Captain Ericsson's second design made use of this law.

If, now, we construct a Concave, Parabolic mirror, the rays will be concentrated on a single point, approaching it from all parts of the mirror. Modifications of this form may be made, by which the focal point may be within the enclosure of the mirror, or at a distance in front of it (Fig. 3).

The simplest form of this mirror is that which is used in locomotives to throw the rays of a lamp ahead along the track in parallel lines. This use of the reflector is exactly the opposite of our application of it; but the headlight reversed is a striking illustration of the solar heating apparatus. This general form — the parabolic,

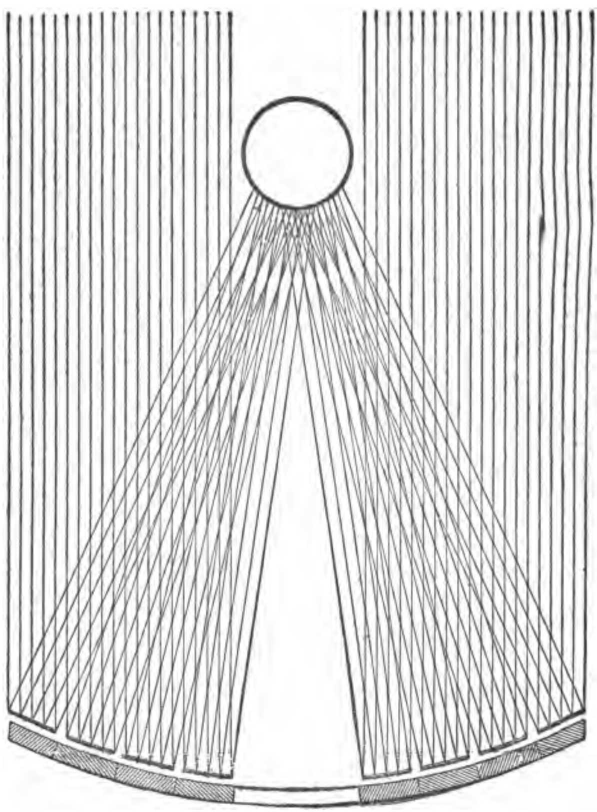


FIGURE 2

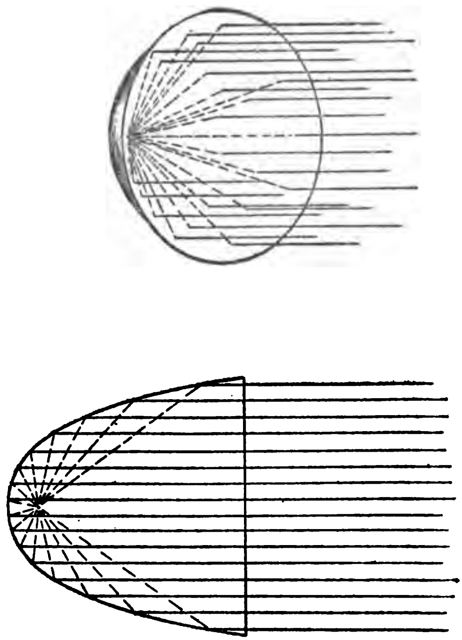


FIGURE 3

concave mirror — may be preserved, while its walls are modified; as separate, *plane* mirrors may be arranged in a frame so as to throw their rays in masses on a central or focal spot, piling up the heat on whatever one desires to heat. Or segments of the parabola may be made, each a plane mirror (chord to the curve), bent in only one direction (radially) to the general direction of parabolic walls. The advantage of the parabolic form is the concentration of rays about one point, losing none, but utilizing all that fall on the apparatus. There is special difficulty in the polishing of the surface thus shaped; and the construction also requires great care. Mouchot, after using it in his early engines, discarded it for a combination of plane mirrors in a truncated cone, preserving, however, the *enclosing* feature of the parabolic mirror. Experience must determine for each manufacturer the form which best suits his special purposes.

Plane reflectors may be of great service sometimes. Stand at the sunny side of a high board fence which has been whitewashed, if you would test this; lay any article on the ground by the

side of such a fence, and see how quickly it will become heated, and how very hot it will get when the fence stands exactly at right angles to the path of the sun's rays. No doubt, simple fences of this sort, extending from east to west or from north to south, may be employed as concentrating apparatus for some purposes; or a pair of fences, inclined a little from the perpendicular, away from each other, may throw down a powerful heat at their base.

THE MATERIAL FOR REFLECTORS.

The finest of all reflectors is one of burnished gold; a thin plating of gold upon a copper or composition metal surface would give almost as perfect effect. Next to gold stands silver. This has been used in the arts a great deal for reflectors of various sorts. Glass plates, silvered, are very practical and effective. Speculum metal, an alloy, has been employed for the reflectors of astronomical apparatus. Copper, burnished, gives very high percentage of reflection; tin, nickel, and other substances are of value. White paper,

especially when calendered or polished, may be proved to have considerable value. Snow gives surprising results. The writer, in Farmington, Me., in 1883, dug a hole in a snow-drift, shaping it in a general parabolic shape with a shovel, and raised the thermometer 60° above the temperature of the surrounding air in a cold day. A scientifically constructed mirror of this sort, made for the Arctic traveller or the resident of a northern clime, and placed on a sled, could be turned to face the sun, and obtain a temperature hot enough for water-boiling and cooking very easily. If the sun can blind the ordinary traveller by its glare, and cause violent optical disease to those who dwell upon its whiteness, it can be made to atone for its cruelties by doing service as a fuel and a kinetic.

Ice is as good as snow for reflecting purposes, if not better. The Arctic explorer of the future must avail himself of these two substances and the heat of the sun in the polar summer day, with its long duration. Who can tell what surprising results will be attained when these agents are harnessed in, more tractable than Esquimaux

dogs, less expensive than coal or wood, obtainable on the largest scale? Taking patterns from home, carrying some portable apparatus for use when not stationed at a particular spot, the coming searcher for the pole will go forth with confidence of victory.

Reflectors have some disadvantages. They are hard to make and difficult to keep in order. Rust, dust, chemical alteration of the metallic surfaces, the careless scratching done by those who undertake to clean them, the wild abrasion of dust-storms in some localities, — such are some of the drawbacks to their use. They are often very expensive. The weight of large ones is formidable; the work of repairing them may require skilled workmen, who are not always available; and other troubles may assail the owner of a reflecting heliostat. But these difficulties are no greater than the burdens which a man assumes when he buys or sets up a steam-engine with fuel-burning attachment; the troubles and expenses are of another sort, but the incubus is probably no heavier on the solar side.

And the lack of cost for fuel will be a large premium on the latter side.

REFRACTION OF SOLAR HEAT.

(C) Solar rays move on in a straight course so long as they are passing through a material of uniform density, where the resistance offered to their progress is the same. But when they pass into a medium of different density, they are bent or *refracted* out of their course. If the body through which they now pass is parallel-sided, like a common pane of glass, the rays resume their former course on leaving it (Fig. 4). If the surface they entered was at right angles to their former course, they suffered no change of direction whatever. If it was inclined at all, they were set aside, so to speak, and then restored to their previous line on leaving. And this is true, whatever their relative density. But if the surface through which a ray enters the new medium is inclined to the surface through which it departs, the ray takes a new course, bending toward the thicker side of the medium. We may suppose

FIGURE 4

that this law applies to all substances which are diathermous, whether they be wood, metal, solid, or liquid; perhaps inventors may develop new lenses out of materials hitherto never thought of for the purpose. But we can *see* the effect of the transmission of rays of light and heat through what we call transparent substances. The best of these is crystal salt, which delivers the largest percentage of the heat which is given to it. Quartz crystal is next; then come the various grades of glass; the latter are the prevalent materials to-day, because of their comparative cheapness. Glass vessels, shaped as lenses, entire or cut, filled with water, gas or any other fluid which is a good transmitter of the rays, furnish the least expensive material. Whatever the material, the laws of refraction are the same. Each substance has its peculiar "refractive angle" or degree of turning the ray aside; each has its special clearness or opacity. It is the province of the manufacturer to investigate these things, and determine for himself which material is the best for the special class of goods he is making; sometimes the cost of raw materials may decide

the question; a great many sorts of refractors may be effective under proper management. The tables of diathermacity are of slight value compared with actual experiment and practical test in operation.

If the two surfaces through which a ray passes are both "plane," and form an angle, the rays passing through will all be turned aside parallel, and will fall in a mass as the rays *reflected* by a plane mirror (Fig. 5). This wedge-shaped or triangular prism separates the normal ray into its separate (prismatic) colors, which differ in temperature, the red rays being hottest; but when we pile one of these *masses* of rays upon another, by refraction from a group of prismatic panes, there is no loss of heat by reason of the dispersion. Indeed it will be possible to obtain some advantage from it if the combination of refracted rays is made with reference to such a result. If one of the surfaces is plane and the other curved in a circular form (*i. e.* making an arc of a circle), the rays will be refracted to a centre or focus; and, if this circular surface is plane in the other direction, like a piece of metal bent

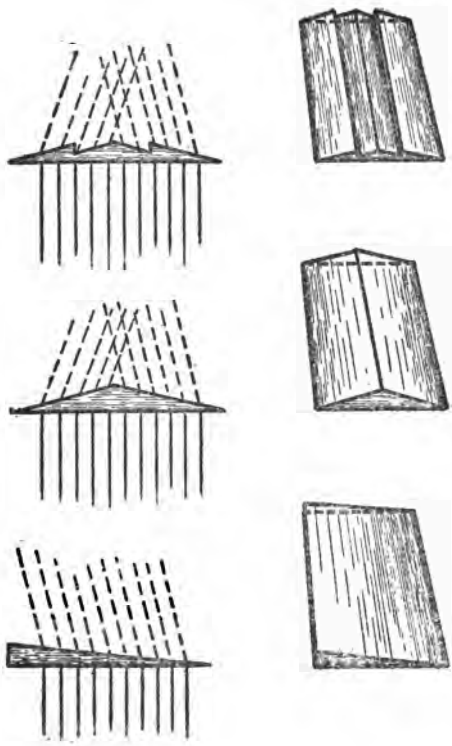


FIGURE 5

in one direction, forming a partial cylinder, then the rays will be focalized along a line. If stopped by a tube or pipe, placed at the focus, they will heat the tube. Captain Ericsson's second solar engine used a reflector which gave this effect; other experimenters have reached the same result with plano-cylindrical lenses, such as we are describing (Fig. 6).

If we have a medium, one of whose surfaces is plane and the other convex, *i. e.* forming a segment of a sphere or bounded by an arc of a circle in each direction, all the rays which enter at right angles to the plane surface (whether that be the entering or the departing surface) will be refracted to a focus at the centre of the curve of which the convex side is a segment, or to a point equidistant on the opposite side. This plano-convex lens is a very common form of condensing lens for the magic lantern and for other uses (Fig. 7).

If we have both surfaces of the lens convex (Fig. 8), the result is precisely the same so far as focalizing the rays to a centre; only the distance of the focal spot is only one-half that of

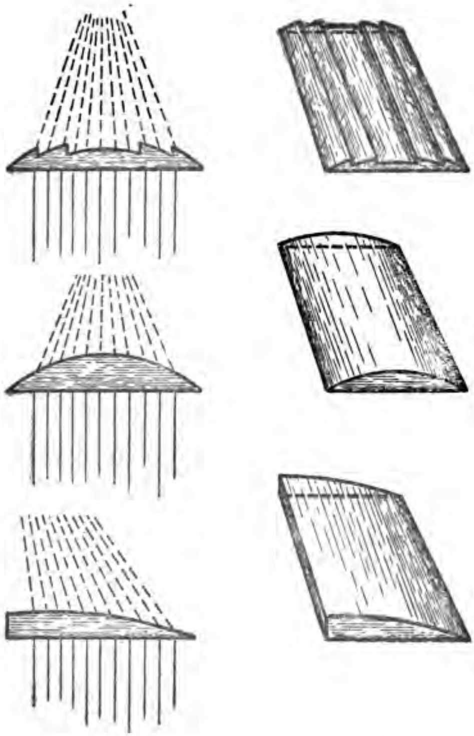


FIGURE 6

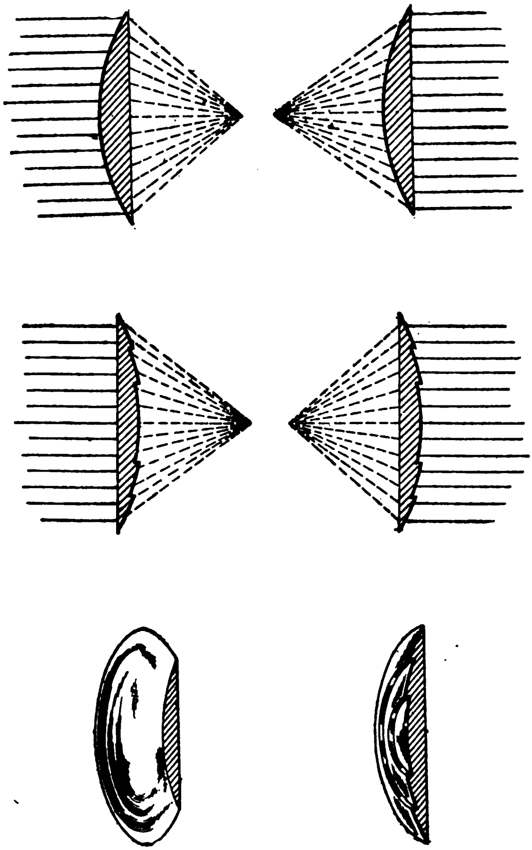


FIGURE 7

the former, since double the amount of *bending* is done in the lens.

The last is the ordinary "burning glass" form. Extraordinary things have been done with large lenses of this form. They are used in the telescope, field-glass, opera-glass, photographic camera, and many other instruments. Manufacturers of such articles have wrought out many problems as to the combination of these lenses with the same and with different forms. Solar engineers may profit by these lessons; there is a very wide field for experiment in the application of the lessons of practical optics to the art of heliodynamics.

A fact of very great importance to this art is the effect of "cutting" lenses. When a wedge is so cut down that the same angle is kept but the wedge thinned in some parts;[1] or when a

[1] A pane of glass, ribbed in such a way as to form a connected series of parallel triangular wedges of the same size, has been invented by a Mr. Pennacook and sold to persons who desired to throw light into dark rooms. Of course such a device cannot increase the light, as is sometimes represented by the ignorant; but the rays are all turned one way, in the direction of the thicker diameter of the triangles. If the panes were made with the trian-

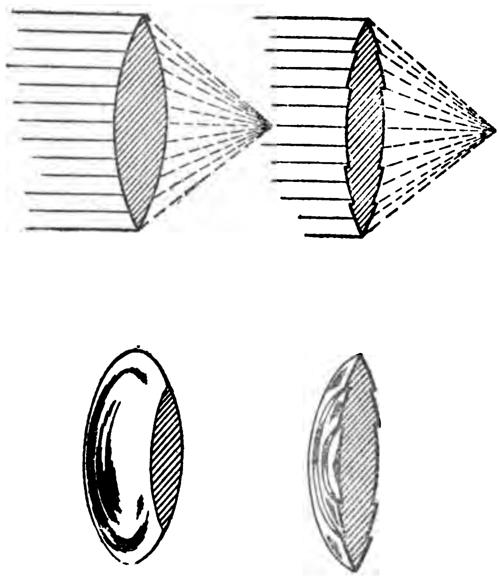


FIGURE 8

curvilinear lens is cut so that its true curve is retained while the thickness is reduced, the refraction is not altered. But a large reduction of the absorbing or retarding power of the lens is made; far more heat will be carried through a "cut" lens than the original from which it was reduced. Each of the foregoing forms is shown in its cut condition above. A familiar example of this may be seen in the lanterns used at switches and other points about a railroad station. Now it is entirely practicable to make very wide lenses for the concentrating of solar heat by cutting them. Of course this is to be done in the original plan, not after the full-thickness article has been cast or rolled. A circular cut lens may be made in sections, like panes of glass, all corresponding to the single plan.

If one would know how magnificent results can be attained by this means, let him examine the glasses of a lighthouse lantern. Each pane or block of glass is a part of a lens system;

gular wedges of different depth, steadily increasing from one side to the other, there would be a concentration of the masses on one band or space.

through all, as one, the rays of the lamp within are thrown out in a sheet of light above the surface of the sea, for the mariner's convenience and safety. By day, the glasses are covered with a curtain; because the sun's rays, striking on them, would be concentrated upon the lamp and set it afire, to the great injury of its form and contents. The cost of these lighthouse lens-systems is very large, for all lamps are feeble compared with the illumination desired from them, so that the manufacturer has to secure a very high degree of accuracy in his refractors. The maker of refractors for solar heat will have so generous a supply of heat to draw from that he need not attain to anything like the same degree of nicety, though following some of the same rules and lessons. And it will be found, after a strong demand has developed, that glass men will overcome the conservatism which has led them to decline applications, hitherto, in many instances.[1] Lenses have many advantages. They

[1] It must be said right here that glass manufacturers are very slow to enter on new work; and they have stood aloof from the task of making lenses suitable for the concentrating of solar heat. The writer applied some years

give a larger percentage of the heat that falls on them than reflectors of the same relative degree of exactness. They require less continual care; if made in sections (panes) they may be put up and repaired by less skilled workmen. Their surface is not in the same danger of corrosion or abrasion as soft metal, like silver. For these and other reasons many will prefer them.

Those who advocate the superiority of reflectors over lenses for solar heat concentration may well consider the fact that we use lenses for our sight in eye-glasses, microscopes, and telescopes to secure the most perfect concentration of *light;*

ago to Alvan Clarke & Sons, of Cambridge, Mass., to produce what he desired at one stage of his experiments; they responded that they were already more than full of orders in their special, astronomical line, and referred him to some French manufacturers. He then applied to the well-known house of Darlot, celebrated for the production of photographic lenses, etc. Mr. Darlot responded that he had already undertaken a similar commission for a French physicist; had spent "some hundreds of francs" in experiments in the matter, and found it impracticable. At the Columbian Exposition the agent of a distinguished French manufacturer of lighthouse lenses was approached on the same errand; standing beside the firm's magnificent display of lanterns of the largest size, we asked him if

why should we not do the same for the concentration of heat?

(D) THE APPLICATION OF SOLAR HEAT.

All that can be done with heat derived from combustion can be done with solar heat. The reader who has carefully read the reports of historical experiments must have noticed how wide is their range. The cook fills her stove with wood or coal to get heat for cooking bread, meat, fish, fruit, confections; she may open her solar oven to the sunshine, and have as much and as steady heat many of the days, in the lands where

it would not be an easy task for such a house to construct "cut-lenses" of suitable character for heat concentration; after careful reflection he answered that he did not think the firm would be willing to undertake the work on account of the high cost involved and the narrow margin for profit.

The very large profits of the lighthouse lens manufacture from the government's liberal appropriations have spoiled those men for the plain, practical business which opens before the maker of solar-heat lenses. But the writer believes that the task presents no real difficulties; and is confident that there will be manufacturers yet found, of sufficient progressiveness and ingenuity, to take this task in hand and make successful results for themselves as well as for the public.

sunshine has sway. The manufacturer of wooden or metallic goods consumes costly stores of carbon, and handles great quantities of ashes, in his attempt to get heat for sawing, planing, forging, drying, bending, cutting, and every way working his materials; his steam or hot-air engine depends on this hard-sought and dear-bought caloric; but the rays of the sun offer him as high degree of temperature when they are condensed and combined suitably. The miner finds on the surface or beneath it masses of rock which contain fortunes; he wants power to hoist, transport, separate, melt, and refine his ores; all this can be done by solar heat properly received, concentrated and converted into kinetic and caloric of the degree he desires. The farmer is in need of stationary engines to thresh, husk, and grind; of locomotives to plough, harrow, sow, reap, mow, pile, draw, to connect him and his work with the marts of the world. The grain-grower and the orchardist and horticulturist join him in asking for water-raising apparatus; and the Auteuil machine and the Pasadena engine are his reply. *Pure country power* may be had as well

as "pure country milk;" and *the costless engine* may replace the expensive ones now enjoyed by but a small part of the people who need them.

ELECTRIC STORAGE OF SOLAR HEAT.

The most significant fact bearing upon solar heat utilization to-day is the development of electric storage. With this feature, the art takes on mighty strength. By the aid of storage batteries, mines may be lighted throughout the day and night; distant cities may be illumined from some "lone, sequestered vale," where sunshine bestows its noiseless benison. Great reservoirs of water may be pumped full in hot days, and drawn from for long days afterward.

By this means a hundred stations may be combined in one grand dynamic unit. It may be that a larger concentration of heat and energy for any purpose can be secured from solar apparatus than from any other source of which we now know. Given a single "section" of land in a favored locality, cover its 640 acres for half their extent with furnaces and motors, leaving the remainder for roads, cabins, repair-shops,

storage-sheds, etc.; stretch wires from side to side, in air or underground, as may be cheapest; bring all their currents to one spot near the railroad, where materials for heating, refining, manufacturing, or what not shall be accumulated; and the great manufacturing centres of the whole world will be outdone. Add section to section, if you please; Niagara itself cannot be stronger than the gathered power of a Nevada ranch or an Arizona claim. If one, why not many such gigantic plants, ranging along the lines of our transcontinental railroads, inviting, not simply manufacturers already at work in other (coal or gas burning) places, but new companies, formed to grapple with some of those cyclopean enterprises which have been dreams thus far in human history, but may be realized through the vast reach of this gratuitous force. Trains of cars can be hauled by trolley or storage-battery methods; city carting, sprinkling, sweeping, and other public work may be done by this means; any public or private operations are feasible by its aid.

One of the most valuable pieces of work to be

performed by heliothermic means is the manufacture of ice. Towns which lie on the coast are now furnished with natural ice at low cost; but interior towns have to meet burdensome freight charges for the article from its northern sources, or else pay prohibitive rates for the manufactured article. With sun heat, the farmer may have his own ice-house and cold-storage room, where he will hold his reserves of butter, eggs, poultry, fruit, vegetables, and other productions till convenient time for shipment and prospects of favorable prices come around.

Ice will enter into the very process of his machinery, too, as in the use of hot-air engines; for the contrast between the temperature of the sun and that of ice, kept in the shadow under the concentrating apparatus, will be great enough to give a capital basis for the cycles of compression and expansion necessary in the hot-air engine.

The world does not yet know how to make the electric current spring directly from substances simply heated; but there may soon be an unfolding of this scheme in season to create

a nascent electric current from some substance by means of solar heat.

Droughts, produced by excess of sunshine, as the world has hitherto viewed the matter, may now be overcome by that very means, since water for irrigation and domestic use lies at no considerable depth in great sections of the country whose surface is habitually parched; and the heat of the sun is available where most needed in this as in many other respects. Famine will leave India when solar engines enter and possess the land.

Solar heat is not different from other heat; it may be used, as has been observed, in connection with any apparatus which could employ the heat of burning wood or coal or oil or gas. As in those cases, there must be a way for the fuel — that is the sunbeams — to enter the heat receptacle, and this door must be always open; this fire can be "banked" by curtains. Clouds will diminish the amount of caloric, and no stirring or increased draft will then help the fireman; devices must be employed to adapt the machinery or other applications to this variability of the

heat, in certain cases, but not in all. Some processes will merely be faster or slower, as the sky is clear or obscured; and the caretaker must test the work being done from time to time, as a cook watches the contents of her oven, or as stationary and locomotive engineers watch fire and "load."

Hot-air engines ought to be a favorite method of applying solar heat because of the absolute inexpensiveness of the material; because air is everywhere, while water, for steam-making, will be hard to get, or absolutely unprocurable in some spots where sunshine is abundant. Ericsson approved of this type of engine for the purpose most heartily. The form of the engine is not within our province to discuss. Treatises on mechanics will inform an inquirer; a genuine mechanical engineer must take up the problem in any given case where large interests are involved.

Steam engines have been the principal method of utilization with Mouchot and other distinguished inventors. The reason may be that the steam-engine has had wonderful development in

its three-quarters of a century, and is well in hand in economies and conveniencies; because, too, the enormous difference between one pint of water and 1,700 pints of vapor makes a tremendous force. Where water is easily obtainable, the steam-engine is to-day the most available, probably, for the development of power from sunbeams.

Ammonia gas has great advantage in its low evaporating point; the Auteuil pumping-plant is an illustration of the manner in which this may be used; this will be a resort of not a few persons for certain uses. Other substances which vaporize at low temperature will come into use of like quality, wherever the requirement is for inexpensive works, and where these easy evaporators are cheap and abundant.

When once we have gathered our heat rays in masses or in focalized intensity, the problems of practical application are not at all different from those which confront a man who has a fire of wood, coal, oil, or gas. *Here is the fire; do with it what you like.*

Any machinery requires human oversight; a

solar bakery for a private house will have to be watched by the housewife or servant, as a coal or wood or oil stove would need to be; a dozen great furnaces with motors attached may all be attended by a single person. It seems probable that this work may be done by persons not the strongest or most athletic; men and women who have too little strength or health to bear common burdens of toil may be able to give the prudent care and trustworthy attention which will be called for in the running of solar apparatus. Of course extensive plants, connected with great manufactories, would have to be cared for by skilled mechanics and engineers.

CHAPTER III.

LOCALITIES WHERE SOLAR HEAT MAY BE OF DOMESTIC AND INDUSTRIAL VALUE.

IN general, any spot where the sun shines is a place for gathering and using its *beams of heat.* For an hour or a day or a small number of days one can utilize this force anywhere. There is an undoubted field for the utilization of solar heat anywhere wherever the sun shines. But the object of the present work is to point out the localities where solar heat may be made a valuable addition to the forces which enrich a people and build up business enterprises.

The *ideal* place for a solar heat plant would be one of those spots in South America where, if we may believe popular reports, no rain ever falls and no clouds linger in any day. Perhaps there are such regions in fact. More likely there

are none in which all possible sunshine is afforded through all the days of the year. But there are many thousand square miles of territory in both Americas and in Asia, Africa, and Australia where the rainy days are very few, clouds rare, and the great majority of the hours of possible sunshine afford clear shining. Eminent examples of this class are Yuma, Arizona, with 301 days of unobstructed sunshine, 52 days partly cloudy, 12 cloudy, and only 7 days of rain in the round year; and Independence, California, with a record of 284 clear days, 72 partly cloudy, and but 9 days when a solar apparatus would be of no use. It has been demonstrated that the heat of the sun penetrates haze and thin clouds, which would be called "partly cloudy" condition; and the rain is concentrated into sufficiently short periods so that interruptions of the working of the apparatus would usually be short.

The long, dry summers of the western sections of the United States are admirable times for the running of the plants we are advocating; and even in winter there are often periods of five or six weeks at a time when the days are rain-

less, so that the working of the furnaces and motors could continue with but brief intervals.

Let us see what the extent of our own *heliothermic area* is. After one has crossed the great River Mississippi and the main trunk of its grand tributary, the Missouri, there begins a vast region of prevalent sunshine. The pastures where cattle in innumerable herds feed; the stretches of wheat and corn land; the ridings where buffalo but yesterday roamed, pursued by red-skinned hunters; the downs over which prospectors have sought not vainly for signs of gold and silver; the lands which give track for railroads, along which the traveller seeks in vain for a shrub as high as a man, till he reaches one plainly called "the Thousand Mile Tree;" those quiet valleys in Utah, where Joseph Smith's followers found refuge; the "plains," over which thousands of miners passed in the fifties, lured by pictures of Eldorado, the alkali plains on which hundreds left their bleaching bones; the slopes of the mighty Nevada chain and the Coast and Contra Costa Ranges, and the wide sweep of fertile land in the valleys of the Sacramento

and San Joaquin systems; the borders of the Golden Gate and its inland seas; the rich lands of Southern California, where Pacific breezes modify semi-tropical heat for the resident; the great majority of the land that is contained in and borders on these regions is the destined home of the solar engine.

Note well, however, that this broad scope of country is not homogeneous. Among these dry places one finds some very moist spots. Mountains which force clouds upward on the windward side allow their moisture to fall on the leeward slope. Not far away from a place of eighty per cent. of possible sunshine, you may come to a region of but half the year clear. And years vary exceedingly, too; which makes the figures of a particular year sometimes really deceptive as to the average conditions. The admirable work now being done under direction of our National Weather Bureau will give us a series of tables soon, whose averages may afford trustworthy data for coming students. The government ought to consider this subject worthy of special and expert investigation, since the re-

sources of our domain are capable of being developed more economically and extensively through this channel than through any other. But enough is known to-day to authorize the statement that, what used to be vaguely called "The Great American Desert," with its borders extending into Montana in the north and Oklahoma in the south, stretching over Wyoming, Colorado, New Mexico, Idaho, Utah, Nevada, Arizona, portions of Eastern Washington and Oregon, and the principal part of California, — in short, what our schoolchildren are now taught to call the "Western Highland States," are generally adapted to the use of solar-heating apparatus.

The following tables, consisting of extracts from reports of the United States Weather Bureau, give figures of sunshine and shade for some places for certain years, which are instructive. They vary, partly from the difference of successive years, partly, it may be, from defective observation in some cases. But they attest the great possibilities of solar heat as an element for the enrichment and development of our Western country.

ITS PRACTICAL APPLICATION

SOME STATISTICS OF SUNSHINE.

Places	1899 Clear	1899 Partly Cloudy	1899 Cloudy	1900 Clear	1900 Partly Cloudy	1900 Cloudy
Belmont, Nev.	194	46	94			
Carlin				166		159
Carson City	155	118	92	192	125	48
Cheyenne, Wy.	113	144	108			
Crane's Ranch, Nev.				227	57	81
Denver, Col.	205	109	51			
Elko, Nev.				198	127	40
Fenelon				181	37	147
Fresno, Cal.	226	56	83			
Golconda, Nev.				211	77	77
Hot Springs				203	38	124
Humboldt				229	40	96
Independence, Cal.	284	72	9			
Las Vegas, Nev.				193	66	14
Lewer's Ranch				182	122	30
Lovelock				208	58	99
Martin's Ranch				263	37	65
Miles City, Mont.	158	135	72			
Mt. Tamalpais, Cal.	196	80	89			
Oklahoma, Okl.	212	72	81			
Owyhee, Nev.				206	82	77
Palisade				230		13
Palmetto				230	71	64
Phœnix, Ariz.	245	86	34			
Red Bluff, Cal.	219	74	72			
Reno, Nev.				162	107	6
Sacramento, Cal.	201	76	88			
Salt Lake, Utah	150	120	95			
San Diego, Cal.	280	40	45			
San Luis Obispo, Cal.	208	95	62			
San Francisco, Cal.	185	104	76			
Santa Fe, New Mexico	234	90	32			
Wadsworth, Nev.						
Yuma, Ariz.	301	52	12			

PERCENTAGE OF POSSIBLE SUNSHINE.

Places	1898	1899
Boston, Mass.	52	59
Cheyenne, Wy.	69	65
Chicago, Ill.	53	53
Columbus, O.	61	53
Denver, Col.	71	75
Eureka, Cal.	45	46
Fresno, Cal.	81	75
Los Angeles, Cal.	76	74
New York, N. Y.	52	60
Mt. Tamalpais, Cal.		73
Oklahoma, Okl.	73	72
Phœnix, Ariz.	84	85
Philadelphia, Pa.	58	65
San Diego, Cal.	73	72
San Francisco, Cal.	71	69
Santa Fe, N. M.	75	80
Yankton, S. Dak.	68	64

Manufacturing establishments have always been located where the power lay at hand. Bangor, Me., Berlin, N. H., and such places drew to themselves the great lumber mills; for they had mighty rivers with falls, at which dams could be built and heads of water made potent for the sawing of tree-trunks into all sorts of what our English cousins call "converted timber." Lowell, Lawrence, Holyoke, and other places similarly furnished, attracted men who

wished to change the down of cotton into muslins and print-cloths, or twine and warp; paper-making, chair construction, machine manufacture, — all these and many more industries were first established by river sides, where direct or indirect currents of water might furnish the power to aid man's skill. After a time, it was found that the irregularity of water-supply was a menace to the constancy of business; cheap coal tempted the operators to put in steam-engines as auxiliaries, and then to use them altogether; and then manufacturing plants were located in such regions as furnished cheap coal, either where it was mined, or where railroads or shipping most conveniently supply it. After natural gas appeared, the trend was toward the seats of this convenience, until the recent check of this source of fuel has stayed the movement. What is to hinder the location of numerous manufacturing establishments in our Western *sun-lands* when once the apparatus for concentrating and utilizing solar heat is brought to a higher state of perfection? The wares which are now taken to California and Oregon, to

Nevada and Washington, to Montana and Idaho, to New Mexico and Utah, from Eastern States and European empires may well be manufactured along the "Plains" and "Bad-lands" and cañons of "The Great American Desert." On these stretches of country, where now the coyote and gopher and jack-rabbit roam, the middle of this twentieth century may see a farming and manufacturing population of many millions, gathered from all parts of the world, enriched and made happy and contented by the very agency that has heretofore rendered the land desolate. Too much sunshine has kept vegetation down and hindered man's activity. Abundant sunshine, concentrated and employed by man, will give those plains and mountain slopes attractions which will draw settlers and capital, and repay toil most abundantly.

At a large number of points there is water a little way below the surface, which may be easily pumped up for irrigation and for domestic uses. The great reservoirs now projected by speculators and government officials, to be constructed at tremendous expense, will afterward require a

large annual outlay for repairs; but the use of sun-motors in pumping water for each farmer and manufacturer to use will be a far larger boon to the country, being more economical and less capable of monopoly and tyrannical management. The people are thus interested to have this sun-power developed most perfectly.

The States which have been mentioned as chiefly endowed with the wealth of sunshine are also opulent in their mineral wealth. Prospectors from California began fifty years ago to discover leads of gold and silver and lead in Nevada and Arizona and Idaho and Montana; while equally adventurous prospectors pushed from Black Hills to Pike's Peak and into New Mexico's ancient gulches. All the way from the Mississippi to the Pacific, the hammer and pick and pan and microscope have done their work. And beside all the magnificent mines which have been developed, there have been wonderful discoveries made which have not yet rendered any man wealthy. Gold and silver and copper and lead and so on are there; proof of that is plain; but the cost of carrying coal or wood for engine

and boarding-house to the spot where the shaft ought to be sunk, the cost of provisioning a crew of miners while they worked the deposits would be so frightful, so far above what the mines now promise, that bold explorers have halted; or, venturing too confidently, have lost all they put into the venture. Now let sun-motors be made at reasonable rates, and these myriad mines will speedily yield their treasures up. A pair of men, armed with one plant of this sort, may do what would now require twenty men; hoisting-gear, haul-out-trams, crushing-stamps, reducing-pans, cooking-ovens, electric lights, etc., will all be available for them.

And this use of the heat of the sun is not to be limited to our own republic's territory by any means. Many lands have large tracts which have heretofore passed as deserts because of the abundance of the sun's downpouring; this very fact is destined to make Algeria, the Soudan, Egypt, India, the table-lands of Ecuador, the arid coast of Peru, and scores of other sections grow opulent when the utilization of solar heat is carried to the point of simplicity and economy. An in-

describably large benefit will accrue to hundreds of millions of people by the subjugation of the sun to common human service. What a motive to the truly humane inventor and capitalist!

All honor to the government of France for encouraging Mons. Mouchot and aiding the application of his work in Algeria; may the British and American governments fall into line with grand force!

CHAPTER IV.

GENERAL DISCUSSION OF THE SUBJECT.

THE use of the heat of the sun has been within human reach all the years of humanity's life. Why has it become no more common? If it is as valuable an auxiliary as this treatise maintains, why has not the public seen the fact? If the desert may be made to blossom, what has prevented Sahara from being turned into one magnificent oasis? If the sun can furnish a prospector the means of testing his discoveries on the spot, the miner and the ranchman a power equal to their needs, why have the magnificent capabilities of great States and Territories remained so long undeveloped?

If "*Vox populi, vox Dei*" — the voice of the people, the voice of God — has not the indif-

ference of the mass of mankind to this subject proven conclusively that the heat of the sun is of no substantial value? Why do not inventors and investors enter into this field in solid phalanx, accompanied by the rush of pens and presses advocating the cause, and why are not common carriers laden with freight of its machinery and produce? Thus the doubter carps at all our histories and reasonings, repeating the ancient sneer: "If it were worth anything, somebody would have long ago found it out and made use of it; rank it with schemes for perpetual motion, with the Keeley motor and sea-water gold mines."

To reply to this is important, for such talk has frightened away many men who had become somewhat interested in the facts of the case; and it must be met squarely or it will continue to hinder the cause. When the writer asserted, twenty years ago, in "Solar Enginery," that "the use of sun-heat is to-day exactly where the art of steam-enginery was on that October morning when Fulton started up the Hudson, in 1807," critics of the pamphlet scoffed. But the parallel is a good one. Scorn and contempt were

poured on Fulton's head while he was making a bold trial of his invention; and every temporary failure in his operations was interpreted as meaning that his theories were chimerical; the public despised his "raft on fire," and it took many years to bring the people generally to appreciate the grand achievement of the inventor. Professor Joseph Henry taught his pupils that strokes on one end of a wire, charged with electricity, would be repeated at the other end (writing at the end *graphein telos*); he explained the whole idea and had an experimental wire stretched around the class-room; but these things did not stir America or England. Morse came, with his alphabet and registering machine, after long years; then the public wondered why the world had so long waited for the means of communication which seemed so natural, so easy. Telephone theories lay in the brain of the English physicist, Michael Faraday, and found expression in his lectures a long time before Graham and Bell gave form and substance to that teaching. How can any man who knows such facts say a word against the *possibility or the*

prospect of developing new resources out of old treasures? The fact that the public has been tardy in the acceptance and appropriation of the natural endowment which we have in sunbeams is not the slightest reason for a cavil at the value of the heat they bring or the practicability of its domestic and industrial use on a magnificent scale.

Further, *the facts* of the matter are unanswerable. The single man, Mouchot, should carry absolute weight with any reader; the individual work of Adams is irrefutable; the strokes of the Ostrich Farm engine are audible everywhere that travellers report what they have observed, and technical men read the *Scientific American.* Solar heat is "no dream;" *it is:* let no man hereafter speak a word of question.

Adventurous business houses have already spent much energy and money in solving practical problems; and the technical schools ought to make much study of the theoretical side of this matter. But every-day work by the comparatively rude methods may be performed by untrained hands. A great amount of value may

be obtained from this vast natural endowment before all the mechanics and dynamics of the subject are wrought out in a suitable fashion; even as steam-engines were a boon to mankind and a source of great individual gains long before triple expansion and vacuum brakes and electric signals were invented, or schools of technology founded.

Some of the arguments which have been brought against the use of solar heat are that it will cost a great deal to construct any extensive machinery; that there are few workmen familiar with the subject, or trained in such construction, to be found in the chief places of mechanical activity and trade; the fact that none of the distinguished trade schools and scientific departments of colleges have noticed the subject to any worthy extent; such are some of the stumbling-blocks thrown in the path of the "promoter" of solar enginery.

But it is to be said that the principal mechanical centres of our land, Boston, Worcester, Lowell, Providence, Buffalo, Pittsburg, New York, Paterson, Philadelphia, Cleveland, Chi-

cago, and how many others, are places of more dark days than sunny ones; that solar apparatus would only be a mockery in their streets; and that the colleges and technical schools are simply the followers of the mechanic, not his leaders. Besides, the regions which have abundant sun are largely under the heel of *that enemy of all industry and science, the mining-stock gambling habit.* San Francisco and Denver could in a trice build up a gigantic, useful art in this direction, if they cared for such things. The great railroad corporations might multiply the population along the line of their roads by developing this industry, if they would show as much disposition to benefit the country as to reap benefit from its people. A general spirit of selfishness has been responsible for the tardy development of this art, which is capable of actually giving to the country, in a few years, more wealth than all our mines of gold and silver have yet bestowed.

Some man or men may arise who will do for this business what one great "Captain of Industry" did for the bicycle; who took a "fad"

and made it a *business* of prodigious dimensions and usefulness; spending millions in advertising the novel article and informing the public how to use and enjoy it; critically scrutinizing every detail of construction, to the end that safety might go to the purchaser as well as profit to the maker; advocating and promoting good roads and good laws to help and guard the growing business and pleasure; bringing the public up to a point where the horseless carriage could be comprehended and developed at its present rate. Such a combination of shrewd business with large public spirit in one or a number of men will find a magnificent field in the development of the solar engine.

To resume the subject of cost, a prominent advantage of solar furnaces is *the saving of fuel-cost*. Steam plants have to be maintained at a vast outlay for that which is destroyed in their operations, — the fuel which they must burn to produce their energy. By all means, the fuel destruction of this day ought to be abridged. We are impoverishing the earth by our fires; every year is consuming the profits of manufac-

turers and diminishing the resources of our descendants and successors. But the sun will give as much to the children of those who become millionaires by its use as to the children of the Indians who have roamed over the desert plains. The absolute freeness of this supply is a point of immense importance, is a lofty argument. This is to be, not alone the horseless, but

THE COSTLESS ENGINE.

And regions which are now feeding on the products of neighboring or distant States will be able to feed themselves and supply others when they avail themselves of the wealth which falls in daily opulence upon their ground.

Increased population will keep up the trade of the country at large; none will grow poorer by the Northwest's enrichment; but the taxable property of our republic will be enlarged, and the whole country will feel a quickening from the growth of a part.

If a plant costs a thousand dollars, the interest on that sum, at the old-fashioned legal rate of

six per cent. per annum, would be sixty dollars a year, or one dollar and sixteen cents a week. A ten thousand dollar plant would cost but six hundred dollars a year for the investment; the simple cost of care, which any machinery must have, is slight compared with the expense of wages or fuel. Mechanism for this purpose is no more liable to accidents or wear and tear than any other kind; and so the whole issue turns on the one fact of the saving of fuel. Now a small steam-engine will consume coal enough to equal the interest on the cost of the plant. But when the supply of fuel is distant, and the price high, the amount saved by the solar furnace is still greater. Wages of laborers are saved by machinery to a large extent; the cheaper the power the larger the saving in this direction as well as the other. The advantage of retaining land for various other purposes, which would have to be absorbed for the *storage* of fuel, is no slight item; the independence of the man who needs no fuel, his freedom from anxiety about supply and transportation, etc., are also of much consequence.

WHAT PROPORTION OF THE TIME WILL SOLAR HEAT BENEFIT US?

Some persons have raised what they consider a serious objection to the use of solar heat in its lack of perfect uniformity; some hours on many days are too cloudy to run these furnaces profitably or at all; some days are wholly or in part rainy or snowy, having no sunshine at all. Every night is debarred from use. Only eighty per cent. (they grant) of possible sunlight can be had, and that means only forty per cent. of the entire twenty-four hours of time. Steam, they remind us, can be kept in operation continually by the use of combustion furnaces. And they ask, would not the loss of time when the sun did not shine be so great that heliodynamic plants would fail to pay the interest on their cost by the slight contribution they might make in domestic or industrial lines? To this the answer may be made that a vast proportion of the purposes for which the solar apparatus would be used are needed only during the waking hours of men and women; that the period of

sunshine is longer than the day which laborers are willing to toil now; and that power to accompany the labor of workmen and workwomen is doing enough in many cases if it simply operates while they are actually at work. Thus the sun's heat will serve the domestic and a respectable portion of the industrial purposes as well as steam now does, which is regularly "shut down" when the operatives are ready to go home at the close of their day of toil.

The storage of power, of which we have treated in previous pages, furnishes a sufficient answer to the question in the case of those operations which have to be continued by second crews of laborers after the sun has set, and those pieces of work which are restricted in their nature to the night, such as street-lighting and the illumination and power-supply of mines at night. By storage batteries these things can be done economically and effectively.

The forty per cent. of possible time in the round twenty-four hours, which may be alleged to be the limit of the *reception* of solar heat, is not, therefore, the total period of our application

and employment of the natural endowment. It must be acknowledged that we have, with the capability of storage, a *practically continuous force.* Thus the heat of the sun is a definite addition to the resources of the world now employed of prodigious content.

ALWAYS ENRICHING, NEVER IMPOVERISHING.

The sun-power is a pure gain to humanity. It subtracts nothing; the world will not be in the least impoverished to-morrow by the fullest use of "visible solar heat" to-day. Just as much sunshine will fall on a region where intelligent, progressive men are using millions of foot-power and feeding millions of people by the aid of solar caloric as on a spot where all goes to waste. The rays that come down on the miner who develops a bonanza by their assistance will not shrink back on finding that result produced,—nor can monopoly increase the price of the fuel!

We must consider that wood and oil and coal and gas are steadily consumed by use. Not only will the coming generations be less comfortably supplied—a thing most of us care very little

about — but the drain to-day may produce distress in our own homes and lay an embargo on our own business to-morrow. The coal strike of the year 1902 has given an appalling lesson on the *slavery* of coal consumers. Contrast with this the *freedom* of the people who receive daily gifts of fuel from the Creator, taking all they wish, all they can use, freely.

Every friend of humanity, then, every man who cares for our race and looks benevolently forward to coming ages, must feel concerned to see this department of economics advance. Every government which builds for to-morrow ought to devote great resources to the rapid development of this science and industry. Every practical business man, who is looking out for opportunities for better investment of capital and labor, has an interest in the matter. Every man, who holds his soul in sympathy with the great plans and benevolencies of the cosmos, should rejoice at the anticipation of such a magnificent enlargement of human business and happiness as this offers: thankfulness as well as opulence must thrive at every advance of solar enginery.

APPENDIX

The first printed book upon the subject of the present volume — and its only predecessor, so far as the writer can learn — was issued from the press of Gauthier-Villars, 55 Quai des Grands Augustins, Paris, France, in the year 1869, with the following title: —

"La Chaleur Solaire
Et Ses
Applications Industrielles
Par
A. Mouchot."

A second edition was published in 1879, —

"Deuxieme Edition
Revue et considerablement Augmentée."

It may be interesting to our readers to see the Table of Contents of this remarkable book. We present a somewhat liberal translation.

CHAPTER FIRST.

Summary. — The sun is a source of most intense heat; experimental proof. — The function of the solar heat on

the surface of the globe; it enters into the movement of life. — Transformation of heat into energy; the mechanical equivalent of heat. — Solar heat is the source of the only natural processes (*travaux*) that man has learned, up to this time, to appropriate. — Possibility of taking possession of solar heat power directly; advantages which would result to certain countries. — A new solar receiver; principles upon which the theory is founded; easy means and slight cost of producing any desired temperature in a boiler by the heat of the sun. — Plan of the work.

CHAPTER SECOND.

SUMMARY. — Of the use of glass among the Ancients. — Concentration of solar heat in a glass flask. — The Arabs used glass vases to perform certain distilling processes by the aid of the sun. — Experiments of De Saussure and of Ducarla. — The heat of the sun is like its light, formed of an infinite number of rays of different sorts. — Uncolored panes of glass behave with heat rays like colored panes with light rays; experiments leading to this conclusion. — Results of the observations of Melloni and Sir John Herschel. — The influence of the nature, substance, source of heat, etc., upon its transmission. — Chemical rays beyond the luminous and calorific rays.

CHAPTER THIRD.

SUMMARY. — Intensity of solar heat at the surface of the sun; results of the observations of De Saussure, De Flaugergues, John Herschel and De Pouillet. — Influence of the dryness or moisture of the air on atmospheric conduction of solar heat. — Intensity of solar radiation at

noon, certainly is the same in summer as in winter. — This is very great at mountain tops as long as the air remains clear; experiments of De Saussure on the subject. — Equatorial regions where the heat is excessive are those where the air is dryest [according to] tests made by Messrs. Soret, Crova, and Violle. — Method of concentrating solar heat upon a surface a metre square in one minute, at the latitude of Paris.

CHAPTER FOURTH.

SUMMARY. — Reflection of light and heat. — Properties of mirrors, spherical, cylindrical, and conical. — Metallic mirrors well adapted for the purpose of reflecting heat. — The reflective power of a polished metallic surface depends upon the nature of the heat rays. — Experiments of Messrs. Laprovostaye and Dessains. — Silver plates reflect solar heat very finely. — Metals which may be used. — Advantages and disadvantages of glass lenses. — Metallic reflectors preferable for ordinary purposes.

CHAPTER FIFTH.

SUMMARY. — History of burning mirrors. — Euclid's treatise on Optics. — The Mirrors of Archimedes and of Anthémius of Tralle. — Works of Arabians. — History of burning mirrors in the Middle Ages and the Renaissance. — Experiments of Magini, Kircher, Villette, Duffay, and of Buffon. — [Their] experiments prove the superiority of mirrors over lenses. — It is not sufficient to consider temperature alone in estimating heat values. — Hoesen's mirror. — Method proposed by Ducarla for protecting from

cooling the articles which are placed at the focus of a burning mirror.

CHAPTER SIXTH.

SUMMARY. — A comparison of the methods (*appareils*) of Ducarla, Herschel, and Franchot. — New solar receiver; its applications. — The action of solar heat upon confined air; means of utilizing the pressure which results. — Raising water by means of the sun; fountains. — The boiling of water; a solar kettle (*marmite solaire*) the cooking of vegetables and [various sorts of] food; solar oven; bread-baking; distilling spirits; melting metals. — The effects on the future of certain countries which would follow the adoption of these operations.

CHAPTER SEVENTH.

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Mouchot has given, as this summary shows, an exceedingly minute, detailed account of *the intellectual movement* toward the utilization of solar heat, well worth the reading and study of a college professor or student of the subject on its theoretical side. But his book, if translated

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